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Green Mind Gray Yard: Micro Scale Assessment of Ecosystem Services

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by

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Abstract

There is a spatial mismatch between the size of the area where people are living and the extent of land needed to ecologically support developed areas. More people are living in urban areas than any time in history, and the resources need to support cities have had to expand to try and meet the demands of increasing urban populations. However, areas of opportunity exist for urban areas to begin to positively contribute towards the available resources in a region. Because a large portion of urban areas is within private control, gaining a baseline understanding of how residents interact with ecosystem services served as basis of this study. Using a survey of residents in the Portland, OR area, correlations between demographic groups and questions regarding their beliefs, attitudes, and behaviors as they relate to vegetation proved that the knowledge of environmental relationships is an important first step in creating pro-environmental behavior. Those reporting a high level of knowledge for ecological system and processes were more likely to value the benefits of vegetation for other associated reasons, such as for recreational activities, aesthetic purposes, and air or water quality. Additionally, survey responses were mapped to spatial data to gain an understanding of the spatial characteristics of neighborhoods in the survey area and how they have changed over time. Overall, the results in the study display trends that can help outreach organizations and municipalities to determine plans to strategically engage the public in a way that could create a net gain in urban ecosystem services.

Table of Contents

List of Tables

List of Figures

Introduction

Everyone on the planet depends on the resources the earth provides, independent of whether one lives in a city or in a rural setting. Just some of the benefits humans receive from the Earth's ecosystems, or ecosystem services, include clean water, food, clean air, hazard regulation, climate regulation, spiritual values, and recreation (*Millennium Ecosystem Assessment*, 2005). Analyses of ecosystem services are usually conducted on a regional scale to help municipalities and scientists determine how ecosystems are changing over time and what benefits ecosystems in that region provide. Additionally, assessments seek to determine the monetary value of the region's ecosystem services, considering elements such as harvest potential, replacement and maintenance costs, etc. Developed areas and cities are frequently within the geographic study area of these regional assessments, but any possible ecosystem services that might be present in the urban areas are often omitted from the study. Urban areas are likely not included in ecology because the spatial characteristics frequently change, meaning they may be more difficult to assess, but they are also inherently degraded by definition. Natural ecosystems are disrupted for urban development. With this mindset, it seems most likely that cities are not included in ecosystem service assessments because they are not seen as places that can make measurable contributions to ecosystem service benefits.

Regions that provide the ecological systems that support human life are also increasing in scale, as resources are drawn from larger geographic areas to try and meet

the demands of increasing urban populations. The world's population is increasingly urban and a majority of residents are living in urban areas with 52.1% of the population (*World Urbanization Prospects,* 2012). In the United States, as much as 82.4% of the population is living in cities (*World Urbanization Prospects,* 2012). With an increasing number of urban residents, actions ensuring that regional resources can support existing residents and the growth of populations need to be taken. When a regional system can no longer support the urban populations within, the extraction of resources often reaches far beyond natural extents and systems are developed to maintain and encourage growth of populations, often to the detriment of other ecological systems (Postel, 2010). For example, many regions have far outgrown their regional watersheds and require additional water resources. River transfer schemes implemented to augment local water supplies are extremely costly, and often include additional environmental costs such as soil salinization, water waste, altered river flows, or the loss of fisheries (Postel, 2010). The energy required to transfer water from the Colorado River into Southern California homes is nearly as many kilowatt-hours as it takes to run a central air conditioning or the refrigerator (Postel, 2010). As the boundaries of ecosystem services stretch to meet the needs of the urban residents, ecosystem services in other regions and cities may be impacted, such as in the case of water (Postel, 2010).

There is a spatial mismatch between the size of the area where people are living and the extent of land needed to ecologically support developed areas. Urban areas are

relatively small compared to the large and increasing regions that support human life. Even though current science does not include or measure ecological benefits present in urban areas within ecosystem service assessments, it is possible that urban areas do have the ability to add to the ecological carrying capacity of the region, instead of simply drawing resources. Consequently, this study seeks to create an understanding of how to begin a new understanding of ecosystem services on a more localized neighborhood scale.

Because land use changes present a number of tradeoffs for ecosystem services, many of these regulating ecosystem services removed for development must be recreated in the built environment with mechanical replacement systems. These mechanical processes can continue to degrade ecosystem services, such as with mechanical cooling as a replacement for vegetative climate regulation. Additionally problematic to the loss of ecosystem function is the issue that the built environment is becoming more uniform. While a light wood frame home in the Portland area may be an adequate building technique because of the mild climate, the same home design in Phoenix requires air conditioning to be livable. As construction has moved away from vernacular building techniques, houses and buildings have been built as though they are independent of site, yet site should still be a primary concern. The development of buildings impacts ecosystem services provided by nature, and these buildings are also affected by nature.

Developing new strategies for increasing the ecological carrying capacity of the region means that scientists, researchers, and activists must find areas of opportunity for encouraging choices that promote ecological functions at a variety of scales. Reducing dependence on mechanical systems with vernacular building techniques and attention to site, as previously mentioned, would be a first step in reducing the demands on regional ecosystem services but it will likely not be the only step needed to create more sustainable regions. Creating systems within the fabric of the built environment that mimic natural processes can also help to regulate wastes and hazards, such as with the use of bioswales and constructed wetlands. Other strategies exist that can even further integrate ecosystem services within architectural systems. In the case of the Living Machine, water used within buildings can be treated and reused through a process that uses a combination of mechanical systems and constructed tidal wetlands on site and even in the building interior to reduce the building's dependence on potable water sources (Todd & Josephson, 1995). Water treated thought this process can then be used again in building systems, such as in restrooms and in heating and cooling systems (Todd & Josephson, 1995).

Industry standards in environmental stewardship programs evaluate buildings on a scale where a reduced impact on the environment gains recognition, as opposed to valuing systems that mimic the ecological functions that were disturbed with development. When opportunities for creating restorative properties in neighborhoods and individual buildings are ignored, and the collective potential that buildings within a

city have to contribute to a region's ecosystem services are unknown. There is also a degree of complacency, where if industry trends don't push to implement elements of site ecology, likely because it is not measured and recorded by programs like Leadership in Energy and Environmental Design (LEED) or in municipal requirements, these important steps towards sustainability are seen as costly add-ons instead of something that is necessary for the vitality of the project or the surroundings. As of now, construction projects that have implemented green building techniques are notable in that they are few and far between, but if all new projects in a particular area of the city implemented elements of passive heating and cooling or on site waste water treatment, what would a neighborhood begin to look like? The EcoDistrict initiative in Portland is beginning to address some of these questions and attempts to achieve many of these goals in a few select neighborhoods but the ideas of resource sharing and waste treatment in neighborhoods is still new, and it is a difficult obstacle to overcome in residential areas for both legal and practical reasons. However, it is possible that there are choices residents can make right now that will benefit individuals and their community without implementing a massive restructuring of neighborhoods and creating new building systems. If members of a community begin to think about the relationship that exists between resources, the built environment, and their role as decision makers, it is possible that the cities can reframe ideals to capture restorative properties.

Application of Small Scale Ecosystem Services

To gain greater precision for both the existing and potential ecosystem services at the community scale it is necessary to first understand the individual component of the urban environment and how that might influence the fabric of the city. If a goal of sustainable development is to become restorative, a general understanding of ecosystem services and their relationship to one another is necessary. In a restorative mindset, it becomes important to understand that the removal or addition of a particular service, such as a tree on a residential property, will present tradeoffs for other services. In a preliminary literature review, thirteen ecosystem services were identified as having strong applicability for neighborhood scale study. Because of the limitations of discussing all services in depth, for the purposes of this study only vegetation will be studied as a benchmark for understanding environmental change at the neighborhood scale. Vegetation was selected due to its importance to cultural, provisioning, and regulating services, as well as its identifiable and malleable relationship with urban residents. Compared to other ecosystem services, vegetation is tangible and readily recognized by the public as natural elements in the urban world that they might have some control over in their own environment.

One of the more important elements to begin to understand is the possible spatial implications of these attitudes and behaviors. In the case of vegetation, it is of particular importance because of the impact personal decisions can make on the landscape of a resident's surrounding neighborhood, and the city as a whole. Currently,

around half of the property in Portland is privately owned at 54% (*Portland Urban Forestry*, 2004). The Portland Climate Action Plan released in 2009 established objectives and actions in eight categories, setting goals to reduce carbon emissions in the benchmark years 2030 and 2050 (*Climate Action Plan*, 2009). One of the categories included Urban Forestry, where the city set a 2030 objective of increasing the urban forest canopy to cover one-third of the area of Portland (*Climate Action Plan*, 2009). The Urban Forestry Management Plan, implemented in 1995 and updated as recently as 2004, also outlines a number of goals and objectives for the Portland area. One of the goals includes increasing the tree canopy to meet a cover of 35-40% in residential zones (*Portland Urban Forestry,* 2004).

The city cannot meet these climate action goals, nor the additional goals outlined in the Climate Action Plan, without a great deal of involvement from the public. Research must begin to understand the attitudes and beliefs that the public holds that could be a barrier to action, and use this information to try and create meaningful ways for the public to create tangible change at a smaller scale. Creating opportunities for individual, neighborhood, and city wide improvements in ecosystem services is likely going to be one of the only ways that residents are going to get involved in pro-environmental decision making that instigates the degree of change required to create more self sustaining regions.

Existing Conditions

In 2004, Portland State University created a report containing the percentage of land covered by tree canopy by neighborhood throughout Portland, along with calculations for the change in canopy cover from 1972 to 2002 using Geographic Information Systems (GIS). The report showed that out of 102 neighborhoods in Portland, 50 neighborhoods showed an increase in canopy cover over the time period and the metro region's canopy cover increased by more than one percentage point (Poracsky & Lackner, 2004). Some neighborhoods showed an increase in canopy cover by as much as 10-20% from 1991 to 2002 (Poracsky & Lackner, 2004). However, levels of canopy cover by neighborhood still varies widely from as little as 2.9% in neighborhoods in and around the Pearl District to as much as 77.3% in neighborhoods surrounding Forest Park, as shown in Figure 1 (Poracsky & Lackner, 2004). The report shows that neighborhoods are changing over time, but disparities still exist.

Additionally from the report, information regarding the Friends of Trees plantings compared to findings of neighborhood canopy change shows a possible relationship between the activity of the organization and the increase of canopy cover in neighborhoods between 1991 and 2002 (Figure 2). Of the 52 neighborhoods in which Friends of Trees planted, only three neighborhoods did not show a net increase in canopy cover (Poracsky & Lackner, 2004). The research presented suggests that Friends of Trees may have a great impact on the spatial data for canopy cover, and while it cannot be determined, it is possible that their activity has a great influence on the behaviors of residents. The authors speculate a number of reasons for the association

between canopy cover increases and organizational activity, including the possibility that residents receiving the plantings are already engaged and predisposed to planting new trees, or that there is a residual increase in planting that grows out of Friends of Trees' activities. While a study of the GIS information alone cannot determine the reasons behind these changes in canopy cover, looking into the motivations and beliefs of the public may begin to offer insight as to why these neighborhoods are changing.

Figure 1: Canopy Cover, City Extent

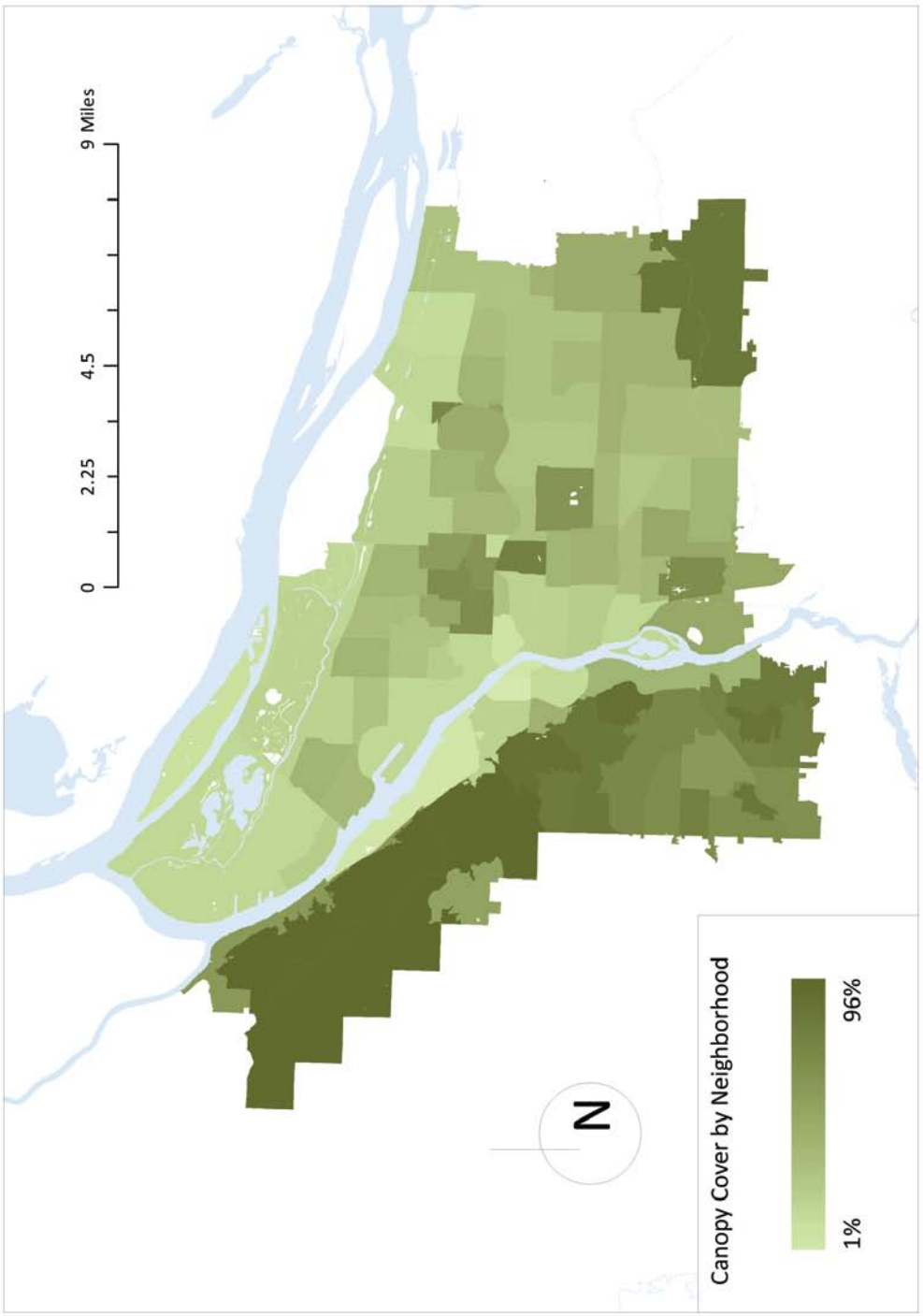
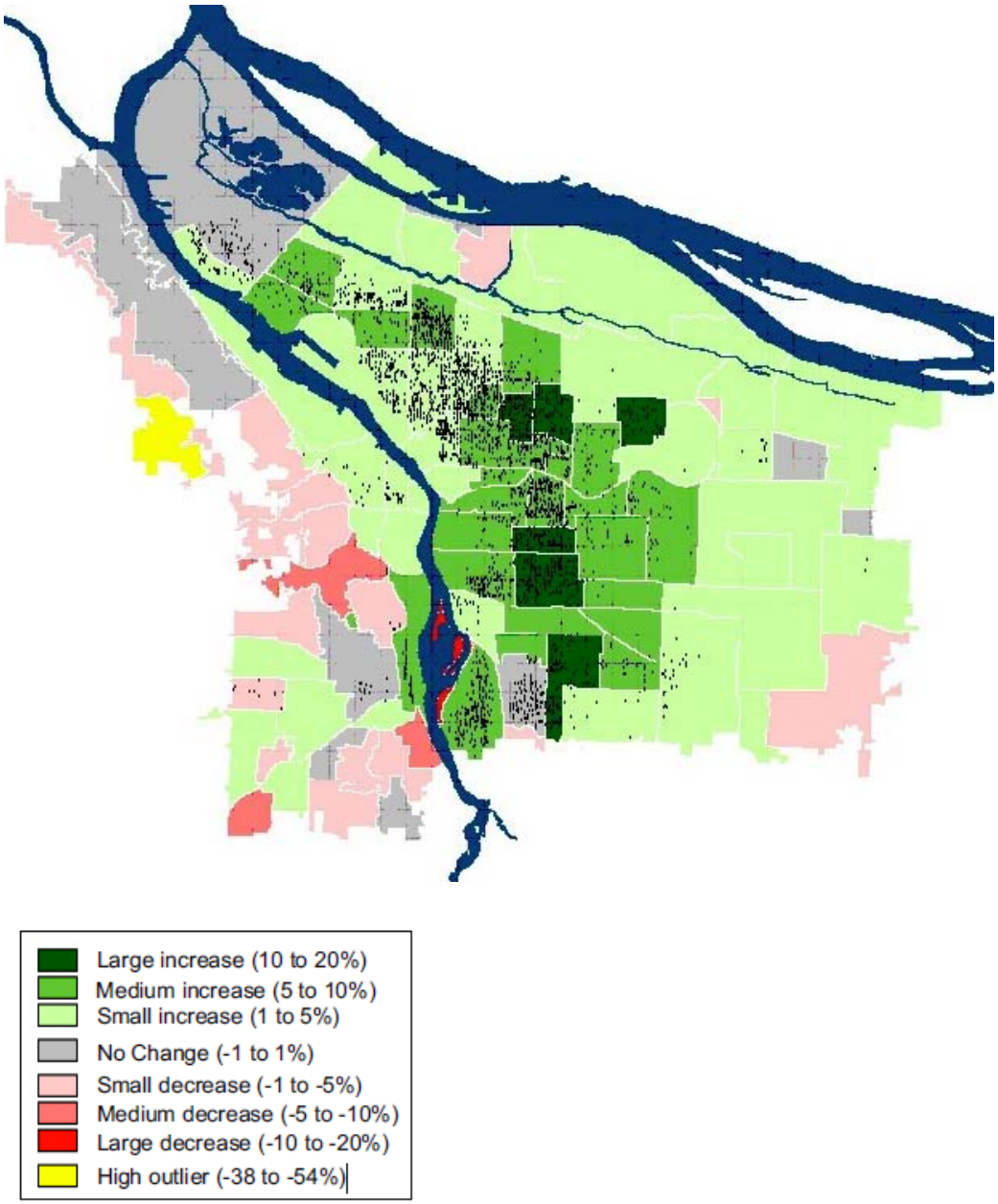


Figure 2: Friends of Trees Plantings (Poracsky & Lackner, 2004)

Dots represent Friends of Trees tree plantings
Base map represents the change in canopy cover by neighborhood from 1991-2002



Application to Research Objectives

Existing research shows that the landscape of Portland is changing over time, and that certain areas of the city are experiencing change at a greater rate than others. Also, in order to meet climate action goals, the city is going to have to engage with residents to meet the benchmarks set. To this end, this research seeks to determine if certain demographic groups have a greater understanding of ecosystem services and their relationships when compared to other demographic groups. Additionally, it is equally important to determine if these groups make changes in their landscape based on their reported knowledge of ecosystem services, and how those changes impact the landscape of the neighborhood.

In the Literature Review, three main components provide a basis for creating a case for ecosystem services in neighborhoods. To gain a greater understanding of how urban ecosystem services are related, information from existing literatures are explored as a basis for the applicability of small scale ecosystem services. There has also been extensive research in the field regarding what are possible indicators for determining levels of vegetation in neighborhoods, such as socioeconomic and lifestyle choices. Lastly, information regarding barriers to sustainability behavior is important to explore, as many of the issues with adopting a new way of thinking is engaging the public in a manner that can influence pro-environmental behavior.

Literature Review

Creating a new scale of understanding for ecosystem services involves discussing three primary areas for the grounding of this research, including ecosystem services and their applicability to urban systems, our current understanding of vegetation and behavior in neighborhoods, and barriers to pro-environmental behavior.

Ecosystem Services

The Millennium Ecosystem Assessment has established thirty services within which four categories, thirteen of which were selected as having potential for neighborhood applicability. Exploration of how these ecosystem services relate to urban areas provides the basis for the literature review. The neighborhood framework may not necessarily imply the spatial extents of a neighborhood, but refers to the reduced scale in contrast with a traditional regional level that would allow for residents and citizens to engage in assessing areas of opportunity.

Supporting services "maintain basic ecosystem processes and functions such as soil formation, primary productivity, biogeochemistry, and provisioning of habitat. These services affect human well-being indirectly by maintaining processes necessary for provisioning, regulating, and cultural services" (Costanza et al., 2011). Because supporting services are necessary for creating and maintain provisioning, regulating, and cultural services, it can be implied that supporting services must be present for any other ecosystem services to be present in urban environments. Because of the

assumption that supporting services must be present for urban ecosystem services to exist, the framework developed targeted only cultural, provisioning, and regulating services as areas of opportunity for study at the neighborhood scale.

Cultural Services:

The cultural component of ecosystem services is certainly one of the most difficult components to articulate, quantify and assess. The difficultly that comes into the study of culture in relationship to ecosystem services is that cultural services provide immaterial and non-consumptive human benefits. “Cultural services combine with built, human, and social capital to produce recreation, aesthetic, scientific, cultural identity, sense of place, or other ‘cultural’ benefits” (Costanza et al., 2011). While this particular service may be difficult to articulate, it may be one of the most important for urban applications and neighborhood studies.

Selected as themes that can have a strong applicability to urban environments include spiritual and religious values, aesthetics, recreation, and ecotourism. Firstly, “increasing empirical evidence indicates that the presence of natural areas contributes to the quality of life in many ways. Besides many environmental and ecological services, urban nature provides important social and psychological benefits to human societies, which enrich human life with meanings and emotions” (Chiesura, 2004). While the motives for using urban parks and greenways could be different for a variety of users,

Chiesura suggests that the social benefits derived from these natural and constructed areas within the urban environment are extensive:

> Contemporary research on the use of urban parks and forests, for example, verifies beliefs about stress reduction benefits and mental health. In a survey among park's visitors a significant relation was found between use of the parks and perceived state of health: those who used local parks frequently were more likely to report good health than those who did not. […] Natural environments with vegetation and water induce relaxed and less stressful states in observers compared with urban scenes with no vegetation. This ability of natural elements to function as "natural tranquillizers" may be particularly beneficial in urban areas where stress is an all too common aspect of daily living. Beside aesthetic, psychological and health benefits, natural features in cities can have other social benefits. Nature can encourage the use of outdoor spaces, increases social integration and interaction among neighbors. The presence of trees and grass in outdoors common spaces may promote the development of social ties. [G]reenery helps people to relax and renew, reducing aggression. (Chiesura, 2004)

Aesthetic ecosystem services can be described as a contrast between the built and natural environments, where the characteristics of a place or natural elements stand out from everyday life and are intrinsically gratifying for the viewer. A pattern of natural areas developed within the built environment has strong spatial implications for urban neighborhoods.

> One pattern of results concerning the nature, object, and ecology of aesthetic experience indicates the importance of managing 'everyday' environments for aesthetic quality. […] Aesthetic experiences tend to occur unexpectedly rather than being sought out by a person, occur most often as a result of interactions with natural objects, and tend to occur in familiar places. These findings suggest that opportunities should be provided for people to experience nature in their home environments as part of their everyday activities (Chenoweth & Gobster, 1990).

Policy at the federal, state, and local levels generally assume that people value aesthetics, but preservation policies are often aimed at selecting areas that are removed from everyday life, ignoring opportunities present in existing neighborhoods. Integrating opportunities within the fabric of urban environment is important, not only for the environmental contributions that can be, but also the social contributions.

Additionally, while they may not traditionally be considered an element of cultural ecosystem services, measures of social cohesion and sense of community may be an important factor for the development of this framework. Because the neighborhood framework discussed here does not relate directly to spatial extents but rather to engaged residents and citizens, and their ability to assess areas of opportunity, the impact of social capital on ecosystem services themselves is another important element to be discussed here. Several factors can contribute to social cohesion and the development of community, including years lived in a neighborhood, level of education, age, and renting or owning a home. These attributes contribute to higher levels of participation and commitment from the community that leads to pride in ownership, investment, and the push for neighborhood services (Buckner, 1988). This is important to note because of issues of equality. Disinvested and less affluent of cities may not have equal access to opportunities for recreational and aesthetic services when compared to more established or higher socioeconomic neighborhoods, but they also will have less social capital to assess their access to these services or work for service integration in these neighborhoods (Buckner, 1988). This is a particularly important

piece of information that should inform policy and neighborhood assessment. Planning for the equal distribution of aesthetic and natural services available to neighborhoods is an important element of planning and policy that can have strong spatial implications on a neighborhood by providing residents with aesthetic and recreational opportunities, services can help to socially empower communities as well. In the case of ecotourism, community based approaches recognize the need to promote the conservation of resources, but also the quality of life for local residents. Local communities can be empowered by ecotourism through economic infusion, psychological and social empowerment (Scheyvens, 1999). Scheyvens (1999) attempts to emphasize the importance of local communities having some control over, and sharing in the benefits of, ecotourism initiatives in their area, rather than being marginalized by the tourism industry (Scheyvens, 1999). In the case of disempowered neighborhoods within urban areas, the literature suggests that it is important to assess if a lack of cultural services may be contributing to low social capital, or if it is the presence of a cultural service, such as ecotourism, that could be presenting a tradeoff for the local community.

Provisioning Services:

Provisioning services are necessary for sustaining human life. Of the services included in the Millennium Ecosystem Assessment (2005), food, wild foods, and fresh water are three services that present real areas of opportunity for understanding how the neighborhood scale can be applied to ecosystem service assessments. The

integration of these services in urban environments can not only help the local users of the systems, but increasing an urban environment's capacity to develop these systems locally will aid in the carrying capacity of the regional system. For example, both food and water security are issues on a global scale. Reducing the size of food sheds and maintaining water supplies on a regional level are major concerns that will reduce reliance on global systems. Reducing systems further to look for areas of opportunity on a neighborhood scale has additional benefits that can contribute to the overall carrying capacity of these services.

Food security is a global issue, and the Millennium Ecosystem Assessment estimates that agriculture, livestock, and aquaculture are the only services that are currently increasing in capacity rather than depreciating (*Millennium Ecosystem Assessment*, 2005). While food production is increasing, this is generally at the expense of other systems. The modification of an ecosystem for the development of an ecosystem service generally presents a number of tradeoffs. For example:

> [A]ctions to increase food production often involve one or more of the following: increased water use, degraded water quality, reduced biodiversity, reduced forest cover, loss of forest products, or release of greenhouse gases. Frequent cultivation, irrigated rice production, livestock production, and burning of cleared areas and crop residues now release 1,600±800 million tons of carbon per year in CO2. Cultivation, irrigated rice production, and livestock production release between 106 million and 201 million tons of carbon per year in methane. About 70% of anthropogenic nitrous oxide gas emissions are attributable to agriculture, mostly from land conversion and nitrogen fertilizer use. Similarly, the conversion of forest to agriculture can significantly change flood frequency and magnitude, although the amount and direction of this impact is highly dependent on the characteristics of the local ecosystem and the nature of the land cover change. Many tradeoffs associated with ecosystem services are

> expressed in areas remote from the site of degradation. For example, conversion of forests to agriculture can affect water quality and flood frequency downstream of where the ecosystem change occurred. And increased application of nitrogen fertilizers to croplands can have negative impacts on coastal water quality. (*Millennium Ecosystem Assessment*, 2005)

Opportunities to increase food and water procurement on a neighborhood scale will not only increase the level of security for a community, but it can also contribute to the preservation of other ecosystem services within the region that provide additional benefits remotely.

There are opportunities for urban agriculture on a variety of scales that allows for a reduced dependence on global systems. As an alternative to international and global food systems, Smit and Nasr(1992) describe urban agriculture as grown within the daily rhythm of the city or town, produced directly for the market, which can include aquaculture, livestock, orchards, and crops (Smit & Nasr, 1992). In addition to improving food security and access to nutritious food, urban agriculture also increases vegetation in a neighborhood and could add economic benefits by in the form of an import substitution industry which can include production, processing, packaging and marketing (Smit & Nasr 1992). Urban areas generally have an abundance of underutilized and available land for food production, both within the city limits and at the periphery. Public lands and rights of way hold opportunities for large scale agricultural endeavors, where "the area of the land and its distribution throughout the urbanized areas are usually on a far greater scale than with other idle public lands" (Smit

& Nasr 1992). Following transportation lines makes these crops especially suitable for quick and easy access to both the market and transportation. These systems already exist in areas of Africa, South America, and Europe, where production along linear land patterns allow for the creation of radial foodsheds, beginning in the city center and extending out into the larger region (Smit & Nasr 1992).

On a smaller scale, underutilized lands within a neighborhood can also present opportunities for residents directly. Community garden plots not only provide vegetation and locally produced food for those that may not have the capacity to garden at their residence, they increase the provisioning capability of the local land, but it can also be socially enriching. Growing Gardens, a Portland nonprofit that helps low income people begin gardening states that "86% of [those assisted] share food with people who do not live with them and 32% say they have met neighbors through gardening. Among Growing Gardens participants, there was a 44% increase in the number of households that ate fresh vegetables five or more times a week, and an 80% increase of the number of households that spent time outside more than five times a week after their garden was installed" (Portland State University 32). Along these same lines, gardening on school grounds with programs like the Oregon Food Bank's Learning Gardens not only offers healthy and locally sourced options for school lunches, but it also teaches children about growing and eating their own food (Oregon Food Bank). A great example of using community landscape for the production of wild foods to serve residents directly is in the suburban Village Homes development in Southern California.

The land within the development has capacity to supply the community with 80% of the need for fresh produce within the development. A post occupancy study revealed while these lands may not be utilized to their full potential as originally drafted during the development, the edible landscape still provides residents with 25% of all their fruit and vegetables (Corbett & Corbett, 2000). In these kinds of privatized areas, communal area food can be grown as a cash crop for a community, where sales of excess crops can also pay for the maintenance costs associated with the cultivation of the commodities.

Lawns provide additional opportunity to use one's own private land as a means for food production. Americans spend thirty billion dollars every year to maintain twenty three million acres of lawn. Around 270 billion gallons of water are consumed a week to maintain lawns, which would be enough to water eighty one million acres of organic vegetables. Lawns use ten times as many chemicals per acre as industrial farmland, and use more equipment, labor, fuel, and agricultural toxins than industrial farming, making lawns the largest agricultural sector in the United States (Flores 2006). There is no doubt that lawns provide opportunities for cultural ecosystem services and that tradeoffs exist for converting these services to agricultural services. However, additional lands outside urban regions are being converted to agricultural services when the largest agricultural sector is already located within urban grounds. Tradeoffs exist, but local private lands can begin to support both the cultural and provisioning needs of residents in unison. Additionally, there are other opportunities in residential locations for agricultural production, such as rooftops and balconies, which can be used for

production in addition to yard space, or where such land is not available for cultivation. Using our community and metropolitan area provides a greater degree of food security on a local level, rather than degrading other ecosystem services far removed from the local foodshed.

Finally, fresh water sources for metropolitan regions and water security are issues that have frequently been described as some of the biggest problems facing urbanized regions today. The Millennium Ecosystem Assessment states that the use of fresh water is increasing, yet the degradation of this particular ecosystem service is happening at levels well beyond those that can be sustained at current rates of use, not to mention future use demands (*Millennium Ecosystem Assessment*, 2005). Urban systems only generate 0.2% of renewable water supplies, while forest and mountain ecosystems serve 88% of the global population (*Millennium Ecosystem Assessment*, 2005). More importantly, global freshwater use expanded at a mean rate of 20% per decade between 1960 and 2000, doubling over this time period but changes to ecosystem services have significantly reduced the amount of available freshwater runoff (*Millennium Ecosystem Assessment*, 2005). Unsustainable use for the built environment, industry, and irrigation has created a global water crisis.

When considering fresh water sources are remaining neutral or declining in their capacity to support to urban areas, one of the most important considerations for these regions would be to promote conservation and reclamation where possible. “According to the U.S. Geological Survey, the United States uses about 1.5 trillion gallons of water

per day. Of this, the vast majority is used for thermoelectric power generation (48%) and irrigation on farms (34%). Water use in and around buildings, from both public water supplies and well water, accounts for about 47 billion gallons per day, or 12% of U.S. water use" (Wilson & Griffiths-Sattenspiel, 2009). Except for the most advanced of residents, people in the United States are using potable water for irrigation, in bathrooms, toilets, washing machines, and even in energy generation. There has been some movement for commercial buildings, through programs like the Living Building Challenge, to begin to use gray water for applications that do not require potable water, but there is still a need to push residential markets to reuse where applicable. A great deal of potable water used at the neighborhood scale goes to uses such as watering lawns, washing cars, flushing toilets, and other tasks where fresh water sources could be used to support other ecological functions. There is an opportunity for neighborhood residents to begin to assess their water usage and consequently reduce demand, through measures such as more efficient fixtures, HVAC systems, any process equipment that requires water as a function of the system, and implementing xeriscaping. Because water reclamation includes treatment of waste water for reuse, this particular area of water conservation is also closely related to regulating services and will be discussed further in this context.

Regulating Services:

Many of the regulating services have a strong relationship with both cultural and provisioning services. Vegetation would seem to be primarily a regulating service, providing climate regulation, erosion control, water and waste treatment, but it is also is a main component in aesthetic and agricultural services. Similarly, fresh water as a provisioning service is closely related to regulating services in that the supply of fresh water is often dependant on an ecosystem's ability to filter and clean the water of sediment and other impurities. Because so many of these systems are interrelated, there are a number of elements within regulating services that can have a strong neighborhood applicability, including climate, erosion, water and waste treatment, disease regulation, pest regulation, and natural hazard regulation.

Disease regulation is a prime example. Population densities make urban environments particularly susceptible, as the spread of diseases and pathogens are reliant on contact networks that exceed a ratio of one to one. For example, zoonoses are generally regulated in natural systems because of low contact networks, but land use changes and population density have a severe effect on an ecological system's ability to regulate disease transmittance. Land use changes reduce regulation due to "an increase in the number of reservoir hosts, an increase in the incidence of infection in reservoir hosts, or a change in the pattern, rate or frequency of contact between reservoir and human hosts" (Cleaveland, Haydon, & Taylor, 2007). National food distribution of contaminated sources increases contacts, making a strong case for local food systems to reduce exposure to linkages.

Vegetation is a critical component of a variety of services and the benefits from urban greenery are numerous. Climate regulation, or more appropriately microclimate for the neighborhood scale, has a strong correlation with vegetation density and open space. Levels of heat stress in neighborhoods is highly correlated with canopy cover, where the implications of tree cover on air-conditioning energy use indicates a possible savings of 5 to 10% per a 10% increase in tree cover (Sailor & Rainer, 1992). Vegetation provides erosion control, where root cohesion and diminished runoff are identified as contributors to reduced erosion (Collins, Bras & Tucker, 2004). In the area of waste and water treatment, "Green roofs in a variety of locations have consistently shown between 60% and 70% retention of precipitation, with an average retention of about 63%" (Dietz, 2007). Green roofs, coupled with bioretention areas as a replacement service for natural systems, or near-natural stormwater management as defined by Gobel et al, can reduce stormwater runoff and pollution concentration (268). Both natural and constructed wetlands can “provide flood control near urban areas, water filtration near sources of urban drinking water, bird watching or other wildlife watching opportunities near urban centers, nursery grounds for commercial or sport fisheries, or habitat for endangered species” (Boyer & Polasky 2004). Vegetation can also be effective natural hazard mitigation, reducing wind intensity in hurricanes, flood control, and additional storm damage reduction benefits. The effects of ecosystem service tradeoffs have been experienced in some areas, and work is being conducted to restore function. Coastal restoration efforts are taking place in the Mississippi Deltaic Plain as a

result of the 2005 hurricane aftermath to regain regulating ecosystem services, such as wetlands and other costal vegetation (Day et al., 2007). The regulating benefits to urban neighborhoods provided through vegetation are numerous, not to discount other benefits that can be derived through vegetation. As part of a framework for neighborhood scale assessment, evaluating the patch dynamics in an area's spatial extents seems to be an appropriate starting ground for assessing access to services and benefits.

Socioeconomics and Vegetation

There are many studies that have looked at predictors and indicators for vegetation, and links to behavior and environmental change. A number of studies cite demographic characteristics, such as education level, income, home ownership, among a number of other characteristics, as indicators and predictors of vegetation structure. A notable study (Grove et al., 2006) of greater Baltimore used groups of residents, created by combining characteristics of urbanization, lifestyle behavior, and socioeconomic traits, to attempt to predict the levels of canopy cover urban areas. Specifically, this study used population density, education, income level , occupation, race/ancestory, family composition, housing, and mobility to create 62 unique categorization axes for the residents of the metro region (Grove et al., 2006). This information, or the PRIZM (potential rating index for zipcode markets) categorization

system, used in conjunction with Geographic Information Systems (GIS) data containing vegetation levels created the basis for the study (584).

The study concluded that median housing age is a significant predictor for vegetation cover in riparian areas, private lands, and public rights of way (PROWs) and that lifestyle behavior will be most significant predictor to the distribution of vegetation cover on private lands (Grove et al., 2006). Additionally specific, "lifestyle behavior was a better predictor of the distribution of tree cover and median housing age was a better predictor of grass cover in PROWs" (Grove et al., 2006).

While the study concluded that there are demographic characteristics that can strongly predict vegetation characteristics in a neighborhood, the motivations for these individuals could only be hypothesized. The authors state that trends show homeowners invest not only in private lands, but also in the PROWs in front of their homes (Grove et al., 2006). A possible theory for this behavior was stated in the study, citing that household "management decisions are [possibly] influenced by a desire to uphold the prestige of its community and outwardly express its membership in a given lifestyle group", or the luxury effect (Grove et al., 2006). As the PROW is not necessarily under a homeowners purview, aesthetically these areas are associated with their homes because of the proximity. Homeowners will likely choose to keep them maintained at an equal level with their own land simply due to association. However, alternate issues in addition, or in place, of the luxury effect could be a factor in the maintenance of the PROWs, such as hazards that may be presented from overgrown street trees (Grove et

al., 2006). Additionally unclear from the research is the fact that these demographics do not create linear trends. As the median housing age approaches 40 to 50 years old, age declines as a predictor (Grove et al., 2006). Understandably, housing age is important as a predictor because new developments often include developing vegetation that needs time to mature, but the decline over larger periods of time suggests that there are additional behavioral trends shaping the neighborhood that influences the vegetation structure. Socioeconomics, the age of residents, and mobility are only a few examples of characteristics that may begin to outweigh housing age. The relationship between choice and demographics would need further study to determine the motivations behind vegetation structure in neighborhoods.

Neighborhoods and Behavior

Because this research examines how to shape neighborhoods in a way that offers replacement services for degraded ecosystem services, looking at information regarding environmental education and behavior are important. Lehman and Geller (2004) describe a number of environmental behavioral interventions, addressing both action and attitudes, which can assist in developing sustaining pro-environmental behavior in a community. Intervention strategies were grouped to include five different topics, including information and education, verbal or written prompts, modeling and demonstrations, commitment and environmental alterations (Lehman & Geller, 2004). Information regarding either environmental degradation or pro-environmental behavior

is seldom enough to change individual action (Lehman & Geller, 2004). The following categories reinforce information and education to assist in instigating change. For example, telling a community group that recycling is important will likely not increase recycling rates without providing additional intervention strategies. However, the additional measures can be as simple as providing a written prompt, such as improving signage for containers to divert recyclables from the landfill, or by creating environmental alterations by providing additional containers to make recycling just as convenient as throwing items in the trash (Lehman & Geller, 2004). In the context of vegetation and neighborhood change, simply telling residents that trees are good will likely not be enough of a stimulus to cause residents to plant new trees on their land. However, if energy providers supplied modeling services for residents showing the potential energy savings from vegetation, they would be more likely to plant new trees because of both the potential savings and acquired knowledge.

Attempting to change individual behavior on private property in the hopes that choices create an urban area with a higher frequency of replacement ecosystem services would prove to be a difficult task. As described by Lehman and Geller, a number of measures are necessary to implement certain patterns of thinking that leads to behavior. In the case of vegetation, it is particularly difficult because in most municipalities, within the extent of the law, residents have complete control over their personal property. There is little to no restriction when it comes to the structure of vegetation on private property, with the exception of hazards and fire concern.

Freedom of choice and other factors certainly can determine personal choices that alter vegetation patterns. Demographics and socioeconomic status can be a factor, as suggested by other studies mentioned previously, but it would seem logical that aesthetics and maintenance requirements are considerable factors in decision making as well.

Interestingly, in Portland, requirements for maintaining trees on private property are beginning to change and directly respond to the problems addressed above. Title 11, entitled "Trees" ("Title 11: Trees", 2011), is an ordinance recently passed by the Portland Bureau of Planning and Sustainability that directly addresses the freedom of individual behavior on private property. Land owners will now be required to obtain permits for pruning branches larger than a quarter inch in diameter, healthy non-nuisance trees greater than 20" in diameter, or more than four trees less than 12" in diameter ("Title 11: Trees", 2011). Part of the permitting process will include a consultation from a City Forester that will provide guidance and education to the resident while assessing the situation for permit approval ("Title 11: Trees", 2011). Removal of non-nuisance and healthy trees that meet these size requirements will require residents to either replace one tree for every tree removed or plant an inch for inch replacement of the trees removed ("Title 11: Trees", 2011).

The goals of the ordinance state that the laws are intended to help the city meet its benchmarks outlined in the Urban Forestry Program, as mentioned previously. Additionally, the document mentions a number of related ecosystem services that the

ordinance intends to address through increasing canopy cover. These services include, providing oxygen and carbon sequestration, filtering for stormwater runoff, reducing energy demands and urban heat island through shading, provide habitat for wildlife, provide a source of food for both wildlife and people, and maintain property values and beauty throughout the city (title 11). Funding dedicated to the ordinance includes an allotment for education and plantings on both public and private property ("Title 11: Trees", 2011). This ordinance is a perfect example of an environmental intervention strategy that provides residents with knowledge of vegetation and associated benefits, but it also provides assistance. While it is possible that many see these restrictions to be an infringement on personal property rights, it directly addresses the missing link between environmental problems and behavior.

Sustainability and Behavior

Generally speaking, one of the biggest barriers to sustainability efforts is often individual behavior. A number of models of pro-environmental behavior cite a number of reasons for barriers to sustainable practices. Hines, Hungerford, and Tomera (1987) that a person must not only have the knowledge of an environmental issue, but they must also be aware of strategies for action to combat their impact (Hines, Hungerford & Tomera, 1987). Additionally, and likely much more difficult to measure, attitudes and beliefs are integral for understanding the gap between knowledge and behavior. People with a strong internal locus of control, or those that believe their actions can bring

change, are much more likely to engage in pro-environmental behavior compared to others (Hines, Hungerford & Tomera, 1987). Those with an external perception of change believe change can only be brought about by those in power, making them less likely to engage in sustainability efforts (Hines, Hungerford & Tomera, 1987). Those with a strong sense of personal responsibility are also more likely to engage in this behavior and commit to sustainability, but these traits still do not determine action or explain environmental behavior (Hines, Hungerford & Tomera, 1987).

Because the importance of increasing sustainability is often described as a move towards global health and future generations, looking to models of altruism and empathy could begin to describe reasons behind behavior. Maslow's hierarchy of needs states that voluntary intentional behavior that results in benefits for another is more likely to be from those who have satisfied their personal needs. This would suggest that these individuals are more likely to act ecologically because they have more resources, such as time, money, or energy, to care about less personal social and pro-environmental issues that are generally well beyond even a city-wide scale (Hines, Hungerford & Tomera, 1987). This assumption would seem logical because measures of resource consumption show that richer nations generally have a greater negative environmental impact and those in lower income brackets tend to rate environmental issues as a low level of importance when discussing pressing problems (Hines, Hungerford & Tomera, 1987).

Existing research suggests that the gap between knowledge and behavior can be linked to a similar gap between the extreme scales of personal characteristics and global problems. Strong small scale influences mentioned previously, such as perception of control, knowledge, attitudes, and personal experiences are strong determinates for action, but a those that have personal experience with environmental degradation are also more likely to act when compared to those that only possess knowledge of the problems (Hines, Hungerford & Tomera, 1987). Personal economics also plays an important role. The affordability of living in a more expensive but walkable community or the price of green purchasing, such as choosing to pay a premium for energy efficient appliances for the potential water savings throughout the life of the appliance, can often force personal behavior. Those that are less affluent likely need immediate financial benefits compared to slow payback over time from reduced gas or water expenses. Additionally, many pro-environmental decisions may not ever see a payback. Decisions made in without the reward of economic payback make a strong case for altruism because these decisions are done in the vein of "doing the right thing". Environmental problems are usually not immediately tangible, and are frequently unable to perceive slow and incremental change. Scientists may not even agree on the cause or the severity of these problems, or may not understand them until the results are irreversible, so it is difficult to expect the general public to have knowledge of these issues and act accordingly.

Research Question

With more than half of the land in Portland under private ownership, the city must work with the public to achieve sustainability goals set in climate action planning and to generally move toward creating a more sustainable city. There has been a great deal of research in the past that explores ecosystem services as they relate to urban environments, but the research is usually in isolation. Studies looking at the level of vegetation in a neighborhood and microclimate often do not take into account the importance of vegetation for recreation or aesthetics. Studies of looking at the opportunities for community gardens and urban agriculture usually do not include an analysis of how an urban orchard might impact the microclimate of a neighborhood. To do comprehensive analyses like this would be resource intensive and likely impossible, but it is important to note that these elements of urban ecosystem services are highly related. Creating neighborhoods with attention to one ecosystem service may create neighborhoods are actually rich in ecosystem services. Even if conducting comprehensive research on these urban ecosystem services is improbable, it may be possible that the understanding of the relationships between ecosystem services could lead to creating environments rich in ecosystem services.

Prior research provides the knowledge that the urban ecosystem services can exist, replacement services are possible, and that these services are greatly interrelated. We also know that knowledge of environmental problems and how to address such problems, through action or inaction, is an important first step to creating pro-

environmental behavior. Demographics have also been linked to environmental characteristics, determining the presence, or lack thereof, and quality of a number of ecosystem services. As urban areas grow and more people live in cities than ever before in history, the ecosystem services supporting these cities are stretched beyond their means. Bringing the scale of ecosystem services to the neighborhood scale, or even a scale as small as the individual parcel, is just as important as measuring ecosystem services at a regional scale because the research suggests there is a great opportunity to create urban areas that can provide substantial regulating, provision, and cultural ecosystem services in these cities, but there needs to be a great deal of involvement from the public to even begin create more self-sustaining regions and rich environments.

Reducing the scale of ecosystem services then becomes important not just for evaluations of the physical characteristics, but in intangible scales as well. If one of the problems with sustainability and behavior is the scale of global problems, can an understanding of the benefits of urban ecosystem services contribute or lead to action? How might personal choices on individual parcels lead to ecosystem rich neighborhoods within a generation?

Vegetation has a strong relationship with provisioning, regulating, and cultural ecosystem services. Its presence in urban areas is something that individuals interact with in both a visual and tangible way, on both public and private land. If we want to understand how to shape neighborhoods, and consequently urban regions, it may have

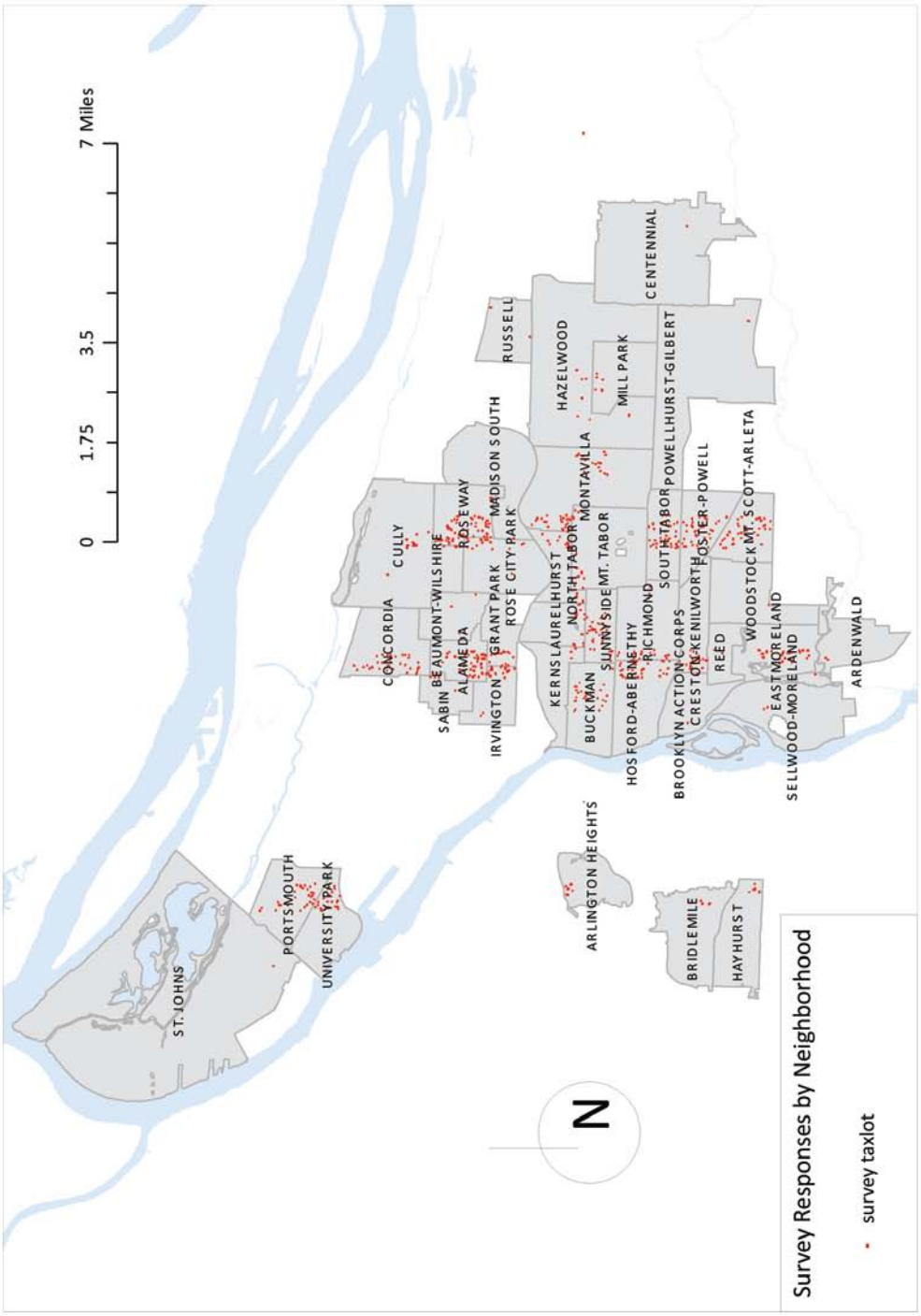
to start at the individual level. Gaining an understanding of the public's knowledge of vegetation's benefits and relationship to ecosystem services becomes an important first step in determining how to address the issue of scale. We know demographics are a determinate for canopy cover and vegetation levels, but are there values or beliefs held by demographic groups that might impact choices on private land, and how might those choices translate to the physical composition of a neighborhood? Because people make conscience decisions on how to care for their property, looking at both revealed survey data with the spatial data with a focus on vegetation is a first step in isolating these issues of scale and understanding.

Methods

As stated previously, vegetation is important to ecosystem services in that it provides innumerable benefits. Also, vegetation is identifiable, tangible, and it can be assumed that residents would be more able to articulate a relationship with vegetation when compared to other ecosystem services due to its presence in urban environments. Particularly because of this relationship, it was clear that vegetation would be an important focus for the purposes of this study.

A 27-question survey conducted in 2008 was used to gain information about the social and behavioral component of neighborhood vegetation (see Appendix A). The survey, entitled "Urban Vegetation: A Survey of Portland Area Residents", selected Portland metropolitan area households by a line intercept sample to gather information regarding individual ideas and practices associated with urban vegetation. The surveys were mailed to a stratified random sample of 5,000 households that spread across incomes and intended to target homes with varying levels of canopy cover (Figure 3). Owner-occupied households were targeted by matching owner address to parcel address, as it was assumed that owner-occupied households would have more control over yard practices. The survey addressed three specific themes: basic knowledge of environmental issues and benefits of vegetation, attitudes and perceptions of the value of urban vegetation on both public and private property, and individual behavior on private property with respect to yard care and water use.

Figure 3: Survey Responses by Neighborhood



Three questions addressed basic knowledge, six questions addressed attitudes, and ten questions addressed physical characteristics and behavior. Questions pertaining to knowledge and attitudes provided a Likert Scale with scales varying between six to nine levels to create data from the responses. Questions regarding physical characteristics and behavior provided either a Likert Scale or ordered options for responses. Options were generally close-ended, but a number of questions provided an open-ended option for respondents. Many of the questions contained sub text that can be considered as their own components for the collection of data. There were 86 separate statements or questions embedded within the survey that provided information regarding knowledge, attitude and behavior. Following these questions, an additional eight questions were asked that addressed demographics. Responses for these questions were either close-ended ordered options or open-ended.

A goal of this study was to examine how residents can interact with urban environments in a way that enhances regional ecosystem services rather than continuing to degrade regions. A research question that emerged from the survey was to see if there was an association between demographic characteristics and personal attitudes or behavior towards vegetation. Using IBM SPSS Statistics, a Pearson Correlation coefficient was computed to examine possible relationships between the survey responses and the characteristics of participants. Statistical analyses have been calculated using the demographic categories of survey respondents as reported in the survey along with the answers to each survey question as the two variables to

determine associations or correlations among them. The demographic categories in the survey included the age of the participant, race, level of education, household income, and whether the respondent owned or rented the property.

This statistical computation was selected because the degree to which demographic categories are associated with behaviors, attitudes, and beliefs is the first step towards understanding possible reasons behind spatial trends. Understanding these associations also assists with outreach and education plans. Because this survey was not constructed for the purposes of this research, some questions do not go into as much detail as would be desired. While the survey provided many questions that addressed knowledge of vegetation's relationship to additional ecosystem services that are valuable for this study, many of the questions did not address how resident's have changed the physical composition of their property or why they have chosen to create changes of any kind. As discussed in the literature review, many of the motivations behind pro-environmental change are influenced by a number of possible elements and it is unlikely that any one experience or characteristic will drive a person to behave with sustainability in mind. Many of the survey questions address topics that are highly personal and subjective. Is likely that more than one factor affects any given variable and that these variables in the survey do not directly correspond with issues relating to the research questions. For example, we already know that knowledge about a particular environmental problem and possible solutions is the first element needed to create environmental action, in this case it could be said that trees provide shade on hot

days and cool surrounding buildings, but additional variables are needed to instigate action. Having received a degree in higher education does not mean that individuals have knowledge of environmental problems or that trees are important for reducing cooling loads. However, using the Pearson's Correlation, we can see if those having completed levels of higher education are more likely make pro-environmental choices without attempting to determine causation.

While reviewing the information provided by the survey, it became additionally clear that evaluating these responses in conjunction with physical data might suggest possible relationships between household characteristics and the amount of vegetation in urban areas. Research presented in the introduction shows that the canopy cover in Portland has been slowly changing over time, but rapidly increasing in certain neighborhoods. Looking at the location of survey responses in conjunction with the physical data regarding canopy levels may provide valuable insights as to how these beliefs, attitudes and behaviors about small scale ecosystem services might actually shape the spatial characteristics of neighborhoods over time.

Responses from the survey have been mapped to the tax lot parcels using Geographic Information Systems GIS data that contained the land cover information for both canopy cover and non-canopy vegetation cover for the city of Portland. Digital land use maps, or Metro's Regional Land Information Systems (RLIS) land use data, provided data for the mapping of the ecological properties in the city, such as areas of water and vegetation, including both non canopy and canopy cover. Portland

Neighborhood Boundaries and Streets were two an additional base use maps obtained through the RLIS database. Survey responses were then geocoded to the map to obtain spatial information for the individual parcels. Mapping survey responses with spatial information allowed this study to examine the connection between the revealed data from the surveys regarding knowledge, behavior and attitudes towards vegetation with the physical characteristics of residential neighborhoods throughout Portland. The percentage of total canopy cover and vegetation cover are compared to highlighted demographics information revealed from the survey and tested for significance.

Results and Discussion

Of the 5,000 surveys issued, 685 surveys were returned showing a response rate of approximately 13%. The Pearson Correlation coefficient computed revealed both positive and negative correlations between five demographic categories and 68 different questions or statements within the survey (see Appendix X). The age of the participant, the education level, and the household income of the participant proved to be the demographic categories with the highest number of correlations, with 37, 32, and 28 significant correlations, respectively. Whether the participant owned or rented the home and race of the participant were the other two characteristics with significant correlations, with one and seven significant correlations to survey questions, respectively. Because of the low number of significant correlations for the last two demographic categories comparatively, only the demographic categories of age, education level, and household income will be discussed in the results section.

Significant correlations were determined at both the 0.01 alpha level and 0.05 alpha levels of significance and the number of correlations found exceeded expectations. Upon examination of the values presented in Appendix B, it is clear that the high number of correlations returned produced a fair amount of relatively weak correlations, but many of the correlations reported below are presented at the 0.01 level. No correlations were found with a greater statistical significance than $r = .265$, $p < .01$ meaning that all of the findings in the survey are more weak than previously anticipated. However, because many of the findings in the appear to be in line with

many of the conclusions suggested in existing research, even correlations at a lower level of statistical significance may be included in the discussion. The goal of the survey analysis is not to find casual relationships or determine what the strongest beliefs are about vegetation, but it is to determine general trends within demographics. Even if the results present lower statistically significant values than previously hoped, these findings in relationship helps to address many of the research questions outlined.

Age

With the highest number of significant correlations, and some of the strongest correlations found in this analysis, age is clearly an important demographic for discussion. The individual ages of participants ranges from 23 years of age to 93, and both the mean and median age of participants is 50 years old.

Table 1: Significant Correlations, Age Demographic and Survey Responses

Demographic Correlations		
Survey Question		Correlation
Basic knowledge of environmental issues and benefits of vegetation		
Q1C	Emissions from public buses are negative	.224**
Q1F	Pollution from manufacturing negatively affects the environment	-.085*
Q1G	Building a new home negatively affects the environment	-.162**
Q1I	Watering your lawn negatively affects the environment	-.149**
Q2A	Neighborhood trees improve local air quality	.091*
Q2C	Lawns improve neighborhood air quality	.233**
Q2G	Public input is required when planning for the city	-.120**
Q2H	The Willamette River is clean enough for swimming	.106**

Q3B	Respondent has a high self reported knowledge of different types of birds	.080*
Q3C	Respondent has a high self reported knowledge of lawn care practices	.102**
Q3E	Respondent has a high self reported knowledge of the hydrological cycle	-.115**
Q3G	Respondent has a high self reported knowledge of climate change science	-.095*
	Attitudes and perceptions of the value of urban vegetation	
Q6A	Vegetation in public spaces is extremely important for physical beauty	-.205**
Q6C	Vegetation in public spaces is extremely important for improved air quality	.102**
Q6E	Vegetation in public spaces is extremely important for cooling and/or shading in hot/sunny weather	.088*
Q6F	Vegetation in public spaces is extremely important for improved social quality of the community	-.136**
Q7B	Vegetation on your own property is extremely important for having a place for recreation or relaxation	-.108**
Q7C	Vegetation on your own property is extremely important for improved air quality	.119**
Q7F	Vegetation on your own property is extremely important for improved social quality of the community	-.102**
Q8C	An important reason for not having vegetation on your own property is because it blocks views	.080*
Q9A	I would like to have more large trees on my property	-.246**
Q9C	Having a garden is important to me	-.089*
Q9E	My neighborhood is full of large trees	.083*
Q9F	Large trees have damaged my home	.115**
Q9H	I have done everything I can to improve my yard	.213**
Q9I	My neighbors work on their yard more than I do	-.080*
	Individual behavior on private property	
Q10B	Of the existing vegetation on your own property, how much would you say is made up of shrubs	.193**
Q11	Who takes care of the vegetation in your yard	.150**
Q12A	Technical expertise is important when caring for your yard	.142** .092*
Q12D	Benefits from vegetation (such as shade) is important when caring for your yard	.092*
Q15A	Chemical fertilizer is never (1)/weekly (6) applied during the summer	.230**

Q15B	Organic or natural fertilizer is never (1)/weekly (6) applied during the summer	.095*
Q15C	Herbicide/weed killer is never (1)/weekly (6) applied during the summer	.184** -.169**
Q15D	Pesticides/bug killer is never (1)/weekly (6) applied during the summer	.199**
Q17	The percentage of your total household water use during the summer for outdoor purposes is 0-25% (1)/76-100% (6)	.120**
Q18	I water in the early morning (1)/never (6) during the summer	-.097*

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

As the age of the participant increased, there participant was more likely to report a high level of self-reported knowledge of lawn care practices, $r = .102$, $p < .01$. However, as the age of the participant increased, they were more likely to report low levels of self-reported knowledge in other areas of expertise, showing significant negative correlations with self-reported knowledge regarding the hydrological cycle, $r = -.115$, $p < .01$, and climate change science, $r = -.095$, $p < .05$. Other correlations suggest that older adults likely to agree with the statements that vegetation does provide some benefits, but those benefits could be outweighed by additional concerns. There was a significant positive correlation between respondent age and the statements that lawns improve local air quality, $r = .233$, $p < .01$, and that vegetation is extremely important for cooling and shading in sunny weather, $r = .088$, $p < .05$, but there were significant negative correlations with the statements that vegetation is important for physical beauty in public places, $r = -.205$, $p < .01$, for improved social quality in a neighborhood, $r = -.136$, $p < .01$, and that vegetation is important for having a place for rest and

relaxation on their own property, $r = -.108$, $p < .01$. Additionally, there was a significant negative correlation with the statement that they would like more large trees on their property, $r = -.246$, $p < .01$, and that the Portland region should have more trees, $r = -.077$, $p < .05$, but there were significant positive correlations with the statements that large trees have damaged their homes, $r = .115$, $p < .05$, and an important reason for not having vegetation is because it blocks views, $r = .080$, $p < .05$.

Education

Table 2: Significant Correlations, Education Demographic and Survey Responses

Demographic Correlations		
Survey Question		Correlation
Basic knowledge of environmental issues and benefits of vegetation		
Q1A	Driving short distances negatively affects the environment	.094*
Q1C	Emissions from public buses are negative	-.146**
Q1D	Bug killers on your lawn/garden negatively affects the environment	.086*
Q1G	Building a new home negatively affects the environment	.185**
Q1H	Heating your home in the winter negatively affects the environment	.126**
Q1I	Watering your lawn negatively affects the environment	.164**
Q2C	Lawns improve neighborhood air quality	-.216**
Q2D	Streamside vegetation improves water quality	.081*
Q2F	The planning department coordinates water supply	-.153*
Q3A	Respondent has a high self reported knowledge of different types of trees	.091*
Q3C	Respondent has a high self reported knowledge of lawn care practices	-.084*
Q3E	Respondent has a high self reported knowledge of the hydrological cycle	.265**
Q3F	Respondent has a high self reported knowledge of ecosystem services	.201**
Q3G	Respondent has a high self reported knowledge of climate change	.211**

	science	
Q3H	Respondent has a high self reported knowledge of environmental policies	.237**
Attitudes and perceptions of the value of urban vegetation		
Q4	The overall importance of having vegetation in our region is extremely important	.110**
Q5	The overall importance of having vegetation on your own property is extremely important	.106**
Q6A	Vegetation in public spaces is extremely important for physical beauty	-.205** .254** .232**
Q6F	Vegetation in public spaces is extremely important for improved social quality of the community	.167**
Q7A	Vegetation on your own property is extremely important for physical beauty	.127**
Q7B	Vegetation on your own property is extremely important for having a place for recreation or relaxation	.078*
Q7F	Vegetation on your own property is extremely important for improved social quality of the community	.083*
Q8A	An important reason for not having vegetation on your own property is because it is costly	-.091*
Q8B	An important reason for not having vegetation on your own property is because it is hazardous	-.102*
Q9A	I would like to have more large trees on my property	.083*
Q9C	Having a garden is important to me	.107**
Q9G	The Portland region should have more trees	.087*
Individual behavior on private property		
Q10A	Of the existing vegetation on your own property, how much would you say is made up of trees	.093*
Q10C	Of the existing vegetation on your own property, how much would you say is made up of grass	-.128**
Q12A	Technical expertise is important when caring for your yard	.092*
Q15A	Chemical fertilizer is never (1)/weekly (6) applied during the summer	-.170**
Q15C	Herbicide/weed killer is never (1)/weekly (6) applied during the summer	-.169**
Q15D	Pesticides/bug killer is never (1)/weekly (6) applied during the summer	-.157**

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

To establish the education demographic, this question in the survey asked participants to indicate their highest level of education across six levels, from less than a high school degree to as high as a post-graduate degree. As the level of education increased among respondents, the participant was more likely to have high self-reported knowledge of environmental topics. There was a significant positive correlation between education and the self-reported knowledge of the hydrological cycle, $r = .265$, $p < .01$, ecosystem services, $r = .201$, $p < .01$, climate change science, $r = .211$, $p < .01$, and environmental policies, $r = .237$, $p < .01$. Additional correlations suggest that those with higher education value vegetation, and specifically value certain types of vegetation over others. There was a significant negative correlation between education level and the statement that lawns improve local air quality, $r = -.216$, $p < .01$, while there was a significant positive correlation with the statement that they would like more trees on their property, $r = .083$, $p < .05$, that having a garden is important, $r = .107$, $p < .01$, and that the Portland region should have more trees, $r = .087$, $p < .01$. Additionally, there was a significant positive correlation between education and the statement that vegetation is important for physical beauty in public spaces, $r = .254$, $p < .01$, and the improved social quality in a neighborhood, $r = .167$, $p < .01$. Lastly and importantly, responses also suggest that this demographic values the benefits of vegetation over other possible concerns. There was a significant negative correlation between education level and the statement that not having vegetation is important because it is costly, $r = -.091$, $p < .05$, and because it is hazardous, $r = -.102$, $p < .05$.

Household Income

Table 3: Significant Correlations, Household Income Demographic and Survey Responses

Demographic Correlations		
Survey Question		Correlation
Basic knowledge of environmental issues and benefits of vegetation		
Q1B	Water flow from paved surfaces negatively affects the environment	-.086*
Q1C	Emissions from public buses are negative	-.167**
Q1F	Pollution from manufacturing negatively affects the environment	-.080*
Q2A	Neighborhood trees improve local air quality	-.111**
Q2C	Lawns improve neighborhood air quality	-.085*
Q2F	The planning department coordinates water supply	-.283**
Q3E	Respondent has a high self reported knowledge of the hydrological cycle	.169**
Q3F	Respondent has a high self reported knowledge of ecosystem services	.145**
Q3G	Respondent has a high self reported knowledge of climate change science	.156**
Q3H	Respondent has a high self reported knowledge of environmental policies	.181**
Attitudes and perceptions of the value of urban vegetation		
Q6A	Vegetation in public spaces is extremely important for physical beauty	.232**
Q6C	Vegetation in public spaces is extremely important for improved air quality	-.172**
Q6D	Vegetation in public spaces is extremely important for reduced potential for floods or erosion	-.145**

Q6E	Vegetation in public spaces is extremely important for cooling and/or shading in hot/sunny weather	-.093*
Q6H	Vegetation in public spaces is extremely important for habitat for wildlife (such as birds and squirrels)	-.136**
Q6J	Vegetation in public spaces is extremely important for helping with medical healing	-.180**
Q7C	Vegetation on your own property is extremely important for improved air quality	-.207**
Q7D	Vegetation on your own property is extremely important for reduced potential for floods or erosion	-.191**
Q7H	Vegetation on your own property is extremely important for habitat for wildlife (such as birds and squirrels)	-.148**
Q7J	Vegetation on your own property is extremely important for helping with medical healing	-.172**
Q8A	An important reason for not having vegetation on your own property is because it is costly	-.080*
Q9E	My neighborhood is full of large trees	.091*
Individual behavior on private property		
Q10A	Of the existing vegetation on your own property, how much would you say is made up of trees	.118**
Q10C	Of the existing vegetation on your own property, how much would you say is made up of grass	-.104**
Q11	Who takes care of the vegetation in your yard	.091*
Q12B	Cost is important when caring for your yard	-.138**
Q12C	How it looks is important when caring for your yard	.086*
Q12E	Environmental concerns are important when caring for your yard	-.117**

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The household income demographic ranges between seven levels, starting at less than $15,000 annually to more than $100,000 annually. Some of the significant correlations found with this demographic are similar to the education demographic, with a few notable differences. This demographic also showed significant positive correlations with self-reported knowledge of the hydrological cycle, $r = .169$, $p < .01$, ecosystem services, $r = .145$, $p < .01$, climate change science, $r = .156$, $p < .01$, and environmental policies, $r = .181$, $p < .01$. There was also a significant correlation between this demographic and the statement that vegetation is extremely important for physical beauty, $r = .232$, $p < .01$. However, an important difference between the correlations for the two demographics reveals itself in the questions pertaining to attitudes and perceptions. There were a number of significant negative correlations between those with high household incomes and the statements that vegetation is important for improved air quality on their own land, $r = -.207$, $p < .01$, cooling or shading in sunny weather, $r = -.093$, $p < .05$, erosion control, $r = -.145$, $p < .01$, wildlife habitat, $r = -.148$, $p < .01$, and helping with medical healing, $r = -.180$, $p < .01$. Cost also generally seems to not be a concern when it comes to vegetation, where there was a significant negative correlation between high income households and the statement that an important reason for not having vegetation on one's own property is because of cost, $r = -.080$ $p < .05$.

Demographic Correlations

It is also important to discuss the relationship between the demographic categories, as a number of groups showed relationships during the analysis. Age computed to show a significant negative correlation with education level, $r = -.208$, $p < .01$, along with household income, $r = -.222$, $p < .01$, and the number of people living in the household, $r = -.319$, $p < .01$. Years in the home along with age showed a very strong significant positive correlation, $r = .690$, $p < .01$. Education computed to show a significant positive correlation with household income, $r = .380$, $p < .01$, and a significant negative correlation with how long they had lived in their home at the time of the survey, $r = -.293$, $p < .01$. Household income showed a significant positive correlation with the number of residents in the household, $r = .197$, $p < .01$, and a significant negative correlation with the length of time in their home, $r = -.206$, $p < .01$.

Survey and Spatial Information

Because significant correlations in the revealed data showed possible shared beliefs and attitudes regarding vegetation for certain demographics, the next step for analysis was to examine possible relationships between these demographic groups and the canopy cover or total vegetation cover on individual tax lots. The mean for the percentage of canopy cover on the tax lots of all respondents was 25.05%, with a standard deviation of 22.07% and a median of 20.18%. The mean for the percentage of total vegetation on the property on all participant tax lots was 55.37%, with a standard deviation of 25.66% and a median of 53.18%. There was a significant positive

correlation between education level and canopy cover, $r = .111$, $p < .01$, and the percentage of total vegetation on the property, $r = .092$, $p < .05$. Household income also revealed a significant positive correlation with the percentage of canopy cover, $r = .131$, $p < .01$. There was a significant negative correlation between home type, rental or ownership, and canopy cover on the property, $r = -.085$, $p < .05$, and total vegetation, $r = -.134$, $p < .01$, suggesting that renters or landlords are less likely to have a high percentage of canopy or vegetation on their plots.

Previous studies cited in the literature review show that demographic characteristics can be used to predict levels of vegetation in urban areas, so a regression analysis was not necessary for the purposes of this study, as these works already suggest the demographics that are important to vegetative cover. This information is likely why demographics questions were included in the survey. What is particularly valuable information gathered from the study is a look into the motivations, attitudes and beliefs of residents regarding vegetation on their own land.

Of the significant correlations described previously, 30 questions or 44% of the significant correlations found with the demographic characteristics described a relationship between vegetation and another service (Table 4). Because of the number of correlations key demographics had with similar questions, trends or patterns of thinking begin to emerge that are worth noting.

Relationship of Vegetation to Other Ecosystem Services

Table 4: Significant Correlations, Demographics and Ecosystem Services

Demographic correlations describing vegetation's relationship to additional ecosystem services				
Survey Question		Demographic	Correlation	Ecosystem Service
Basic knowledge of environmental issues and benefits of vegetation				
Q1D	Bug killers on your lawn/garden negatively affects the environment	Education	.086*	Pest Regulation
Q1I	Watering your lawn negatively affects the environment	Age Education	-.149** .164**	Water Regulation
Q2A	Neighborhood trees improve local air quality	Age HH Income	.091* -.111**	Air Quality Regulation
Q2C	Lawns improve neighborhood air quality	Age Education HH Income	.233** -.216** -.085*	Air Quality Regulation
Q2D	Streamside vegetation improves water quality	Race Education	-.081* .081*	Water Purification
Attitudes and perceptions of the value of urban vegetation				
Q6A	Vegetation in public spaces is extremely important for physical beauty	Age Education HH Income	-.205** .254** .232**	Aesthetic Values
Q6C	Vegetation in public spaces is extremely important for improved air quality	Age HH Income	.102** -.172**	Air Quality Regulation
Q6D	Vegetation in public spaces is extremely important for reduced potential for floods or erosion	HH Income	-.145**	Erosion Regulation
Q6E	Vegetation in public spaces is extremely important for cooling and/or shading in hot/sunny weather	Age HH Income	.088* -.093*	Climate Regulation
Q6F	Vegetation in public spaces is extremely important for improved social quality of the community	Age Education	-.136** .167**	Social Relations
Q6H	Vegetation in public spaces is extremely important for habitat for wildlife (such as birds and squirrels)	HH Income	-.136**	Pest Control Pollination Sense of Place Aesthetic Values Recreation and

				Ecotourism
Q6I	Vegetation in public spaces is extremely important for reducing crime	Race	.088*	Social Relations
Q6J	Vegetation in public spaces is extremely important for helping with medical healing	HH Income	-.180**	Spiritual and Religious Values
Q7A	Vegetation on your own property is extremely important for physical beauty	Education	.127**	Aesthetic Values
Q7B	Vegetation on your own property is extremely important for having a place for recreation or relaxation	Age Education	-.108** .078*	Recreation and Ecotourism
Q7C	Vegetation on your own property is extremely important for improved air quality	Age HH Income	.119** -.207**	Air Quality Regulation
Q7D	Vegetation on your own property is extremely important for reduced potential for floods or erosion	HH Income	-.191**	Erosion Regulation
Q7F	Vegetation on your own property is extremely important for improved social quality of the community	Age Education	-.102** .083*	Social Relations
Q7H	Vegetation on your own property is extremely important for habitat for wildlife (such as birds and squirrels)	HH Income	-.148**	Pest Control Pollination Sense of Place Aesthetic Values Recreation and Ecotourism
Q7I	Vegetation on your own property is extremely important for reducing crime	Race	.106*	Social Relations
Q7J	Vegetation on your own property is extremely important for helping with medical healing	HH Income	-.172**	Spiritual and Religious Values
Q8C	An important reason for not having vegetation on your own property is because it blocks views	Age	.080*	Aesthetic Values
Q8F	An important reason for not having vegetation on your own property is because it doesn't fit with the neighborhood	Race	.084*	Sense of Place

Individual behavior on private property				
Q12C	How it looks is important when caring for your yard	HH Income	.086*	Aesthetics
Q12D	Benefits from vegetation (such as shade) is important when caring for your yard	Age	.092*	Climate Regulation
Q12E	Environmental concerns are important when caring for your yard	HH Income	-.117**	
Q15A	Chemical fertilizer is never (1)/weekly (6) applied during the summer	Age Education	.230** -.170**	Nutrient Cycling
Q15B	Organic or natural fertilizer is never (1)/weekly (6) applied during the summer	Age	.095*	Nutrient Cycling
Q15C	Herbicide/weed killer is never (1)/weekly (6) applied during the summer	Age Education	.184** -.169**	Pest Regulation
Q15D	Pesticides/bug killer is never (1)/weekly (6) applied during the summer	Age Education	.199** -.157**	Pest Regulation

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

There is an important difference between demographic groups as far as the quality or types of vegetation is concerned. The age demographic stated that both trees and lawns improve air quality, $r = .233$, $p < .01$, and that watering lawns actually benefits the environment, $r = -.149$, $p < .01$. Additionally, a significant correlation was found between the age of the participant and the percentage of their total household water use during the summer for outdoor purposes, $r = .120$, $p < .01$, where that a statistically significant portion of older participants use 76-100% of their water consumption on outdoor watering. While the focus of this research is on canopy cover, these trends are important to highlight because it suggests a preference for vegetation. These preferences could be maintenance related, but conclusions such as this can only be

speculated. However, the correlations do suggest that older adults might prefer grass to canopy for maintenance concerns, but additional correlations suggest that these respondents are still unhappy with the level of care needed to maintain lawns. If this information were to be used in outreach, the correlations suggest that teaching older adults xeriscaping techniques would reduce maintenance concerns while possibly increasing levels of biodiversity on these plots.

Those with a higher level of education had a higher self reported knowledge of ecological systems, as stated previously, and this knowledge actually did seem to show some relevancy in questions eluding to other ecosystem services. This group showed significant correlations with statements such that lawns improve air quality, $r = -.216$, $p < .01$, and watering negatively affect the environment, $r = .164$, $p < .01$. Responses in this group also suggested a weighted valuation of vegetation by stating that their yard has a high percentage of trees, $r = .093$, $p < .05$, and a lower percentage of grass, $r = -.128$, $p < .01$. The correlations found in these types of questions with the education group suggests that those with higher education seem to recognize that maintenance requirements for manicured lawns has a negative effect on other ecosystem services.

These results also could suggest that older adults might see additional driving benefits to having a yard or other plants, yet they consistently revealed significant negative correlations with questions related to other ecosystem services, particularly cultural services. There is significant correlation with the importance shade provides with the age demographic, $r = .092$, $p < .05$, but any other benefits are few and far

between. Older adults were more likely to disagree with the statements that vegetation was important for recreational purposes, $r = -.108$, $p < .01$, that it is important for social quality in a neighborhood, $r = -.136$, $p < .01$, or that it is important for physical beauty, $r = -.205$, $p < .01$. The high use of water for these residents in lieu of these other factors suggests that there is possibly a luxury effect happening ,where older adults are concerned with keeping up neighborhood appearances as significant positive correlations were found in each of the three questions regarding the frequency of pesticide and fertilizer use. They also stated that they have done everything the can to improve their yard, $r = .213$, $p < .01$, yet there was not a significant correlation with the statement that how the yard looks is important. Many complaints about trees suggest that many of the negative correlations could possibly be attributed to large maintenance concerns, where older adults are more likely to state that trees have damaged their homes, $r = .115$, $p < .01$, that they would not like more large trees on their property, $r = -.246$, $p < .01$, and that the city of Portland should not have more trees, $r = -.077$, $p < .05$. There was also a significant negative correlation with the statement that having a garden is important, $r = -.089$, $p < .05$. If maintenance concerns are one of the biggest factors for this group and social benefits and aesthetics are not a primary concern, the drivers that would cause this demographic group to water at a high percentage and apply fertilizers or pesticides on a weekly basis are unclear. Air quality being one of the only benefits highlighted by this analysis would not seem to be

a strong motivator for maintaining personal property, given the correlations found in this demographic.

As education and income levels were highly correlated with one another, it is understandable that these groups had many similar correlations and there were some similarities when it comes to identifying vegetation's relationship to other services. Those with high household incomes also expressed a high self reported knowledge, but there were a correlations stand out as unique to this group that suggest the luxury effect is strongest in those earning higher incomes and that this concern outweighs many other ecosystem services that have a relationship with vegetation. Cost was not listed as a concern in caring for one's yard, $r = -.138$, $p < .01$, and this is the only demographic to correlate with the statement that how the yard looks is important, $r = .086$, $p < .05$. Additionally regarding aesthetics, there was a correlation with the statement that vegetation is important for physical beauty, $r = .232$, $p < .01$. Alarmingly, there was a consistent trend of negative correlations with questions that refer to ecosystem services that can easily be replaced by mechanical replacement services in modern building and lifestyles. High wage earners are the only group to correlate negatively with statements such as vegetation is important for habitat for wildlife, $r = -.136$, $p < .01$, for erosion control, $r = -.191$, $p < .01$, for shading or cooling, $r = -.093$, $p < .05$, and for medical healing, $r = -.172$, $p < .01$. While high wage earners significantly correlated with high self reported knowledge in exactly as many statements and the

education demographic, these results suggest that other concerns may trump the importance of vegetation, but the root of those concerns can only be speculated.

Changing Vegetation

Surprisingly 409 participants, or 60% of the surveys returned, reported having made "significant changes" (question 13, Appendix A) to the amount or type of vegetation on their property in the time they had lived in their home at the time of the survey. As mentioned previously, it is of particular interest for the purposes of this research to develop an understanding of how motivations, either from knowledge, aesthetics, etc. translates to environmental change in neighborhoods. While no demographic had a strong correlation with this question, meaning that no group is consistently making changes compared to another group, a look at the descriptive statistics is informative at the least. Interestingly, the mean canopy cover percentage for the majority of groups is above the mean percentage for the aggregate. Additionally, the mean for those in both the demographic and those with education that made significant changes are significantly above the mean of the aggregate of those that reported only that they made significant changes. It is possible that those with a higher level of education that choose to make changes to their vegetation levels are increasing their canopy cover, while the general population is making changes to decrease the amount of vegetation on their properties. It is also possible that those with higher incomes and education levels, as they are significantly correlated, live in

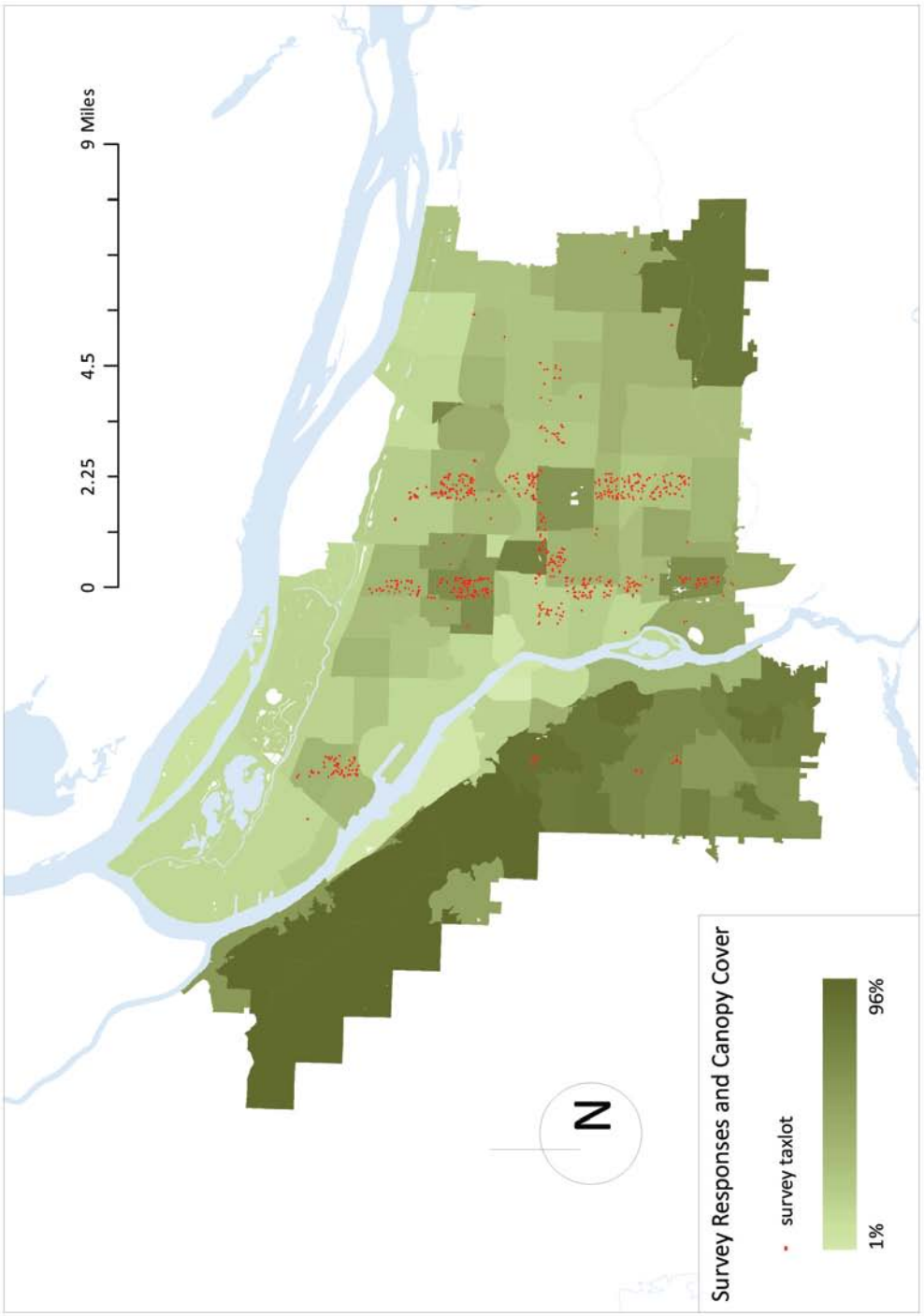
higher income neighborhoods that generally have a higher canopy cover when compared to neighborhoods with statistically lower income groups.

Question 13 does not ask specifics about these changes, so it is impossible to know from the data collected whether canopy has been increased or decreased, if lawn has been removed, shrubs have been added, or any other possible changes. It also does not touch on why the respondent has made changes, or if the changes relate to other environmental processes, but many possible reasons behind these changes can be speculated from the correlations found through the survey. Such as, it is possible to imagine from the data that an elderly woman living alone would like to reduce her yard maintenance and remove large trees over time, while a new home owner might like to add shrubs and reduce their amount of lawn.

Spatial Data

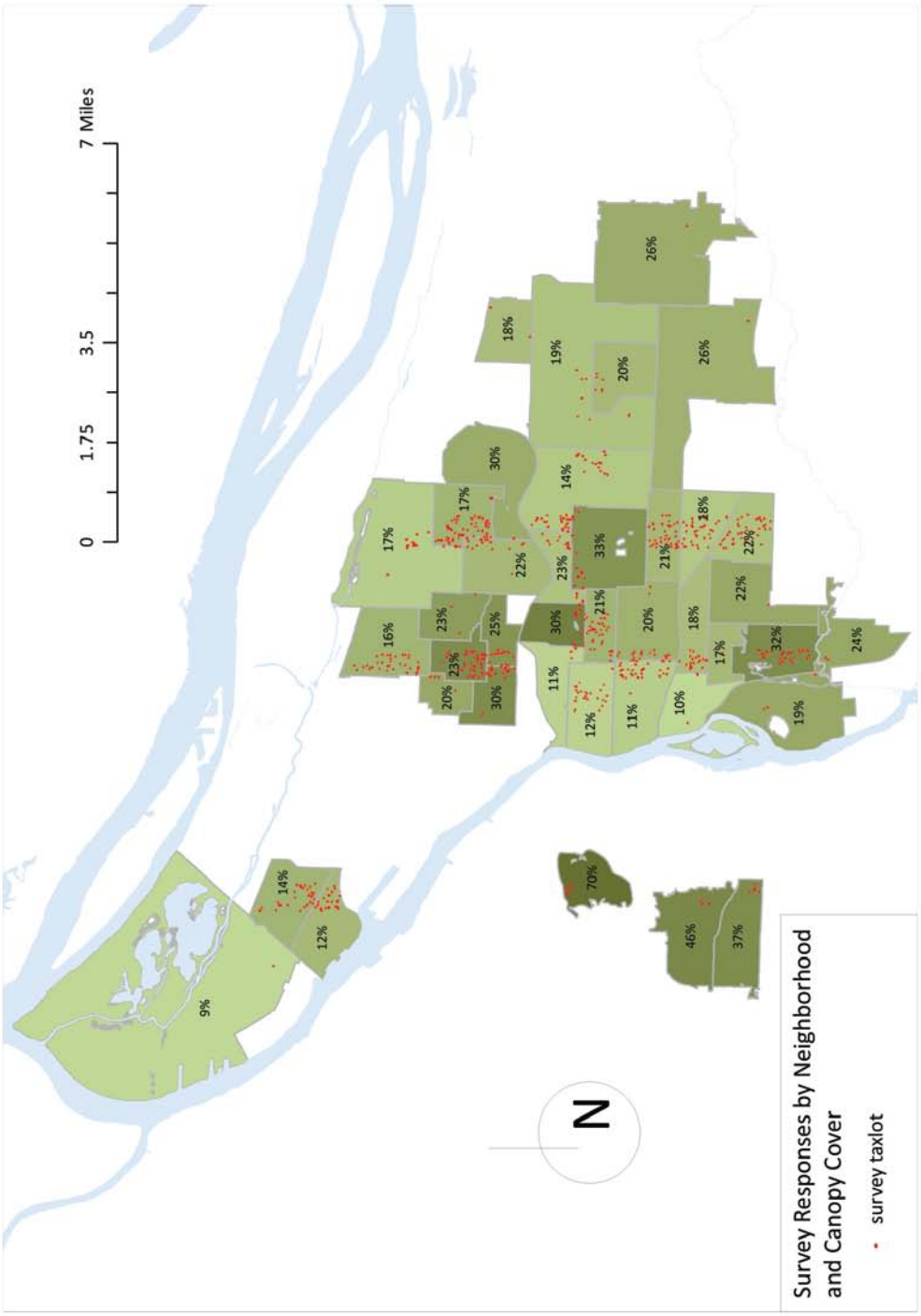
Because a large portion of the city and the canopy is within private control, understanding how the survey results correspond with the spatial information is an important step in understanding the role personal attitudes may have on the city's goals of increasing canopy cover. Figure 4 shows the level of canopy cover throughout the city at the time of the survey by neighborhood along with the locations of the survey responses. This map show the diverse geographical sampling of the participants and the variety of vegetation the respondents may engage with on their property, but also in their immediate surroundings that could influence a number of responses.

Figure 4: Canopy Cover and Survey Responses



The canopy cover report from Portland State University previously mentioned showed that out of 102 neighborhoods in Portland, 50 neighborhoods showed an increase in canopy cover over the time period and the metro region increased in cover by more than one percentage point (Poracsky & Lackner, 2004). Some neighborhoods showed an increase in canopy cover by as much as 10-20% from 1991 to 2002 (Poracsky & Lackner, 2004), including the neighborhoods Beaumont-Wilshire, Alameda, Roseway, Sunnyside, Richmond, and Woodstock. Interestingly, all six these neighborhoods are represented by at least one participant from the survey, with a very heavy clustering of responses from residents located in Roseway, Alameda, Sunnyside and Richmond (Figure 5). The following figure shows the neighborhoods with survey responses and their corresponding canopy cover percentage (Figure 5). Some of these neighborhoods, such as Sunnyside, Roseway, and Richmond, currently only have 21% of canopy cover or less. If these areas have increased in canopy cover by 10% or more over the last 20 years to a total of 21%, the total percentage of canopy has more than doubled in these neighborhoods. With 25% of respondents reporting having lived in their homes for 20 years or more, including residents in each one of these particular neighborhoods with high leveled of increased canopy, it is fair to say many residents have likely encountered a great deal of change in their neighborhoods. The small sample size of some residents in particular neighborhoods prevents statistical analyses between particular responses and neighborhood canopy, but it is important to note that 59% of those living in their home for more than 20 years state that they have made significant changes to the

Figure 5: Survey Responses by Neighborhood and Canopy Cover Percentage



amount or type of landscape at their home. While it is impossible to tell how and why residents have changed their landscape, overall increasing trends along with survey results suggest a need for additional research into how residents might be changing their private plots and how these decisions might be impacting the neighborhood and city landscape.

Another important point developed by the canopy report from is the "Friends of Trees" Effect (Figure 2) (Poracsky & Lackner, 2004). All six neighborhoods mentioned previously received a high number of tree plantings, but the map suggests that there was also a proportionally high number of tree plantings in neighborhoods such as Boise, Overlook, Humbolt and Arbor Lodge. Unfortunately, these neighborhoods were just outside the sampling for the survey so any possible effect residents in those neighborhoods might have encountered is not included in this study. The research presented suggests that Friends of Trees has a great impact on the spatial data for canopy cover, and while it cannot be determined, it is possible that their activity has a great influence in the responses and behaviors of residents. It is possible that the organization may be responding to residents that are already engaged, but because they seek to educate residents as well as plant trees, an interesting next step in light of this research could be to survey in areas of organizational activity to gauge education level and the amount or type of vegetation change on private property compared to residents in neighborhoods without such involvement.

Limitations and Alternative Research

The research shows that residents are actively changing the amount and type of vegetation in their yards, and that it is possible that those with knowledge of the relationship between vegetation and ecosystem services are making changes in a way that adds to the overall level of ecosystem services in urban areas.

While not done within the scope of this research, It would be possible to test responses to questions within the survey to see if a given belief or behavior appears to have a causal relationship to another, but this step still does not address the physicality of how residents are changing their yards. We still do not know if choices are being made to increase or decrease canopy based on the survey responses. GIS data suggests an overall increasing pattern in many of the neighborhoods, but the data with regard to time and spatial characteristics is missing at the individual household level to determine what motivations alluded to in the survey might be behind net changes. What would have been most beneficial in addressing the research questions would have been to see if a casual relationship exists between survey responses regarding attitudes and beliefs and the types of changes performed by the owner, if any.

Conclusion

Many studies have been conducted that link canopy and vegetation with demographic characteristics as a means to predict vegetation in neighborhoods, but there is little research that seeks to identify the reasons behind why these personal characteristics have an effect on the environment. If the city has a goal to increase the canopy cover of neighborhoods and the city as a whole, then research needs to begin to target not only the indicators of canopy cover, but more how these predictors can be altered and influenced. As regions move toward sustainability and reach to achieve climate action goals, it is not enough to say that economically depressed neighborhoods are likely going to present lower canopy cover because of a number of demographic characteristics. Change begins with understanding the problem, how canopy cover can be determined by a neighborhood's demographics, but the next step becomes altering perception though education and creating experiences for individuals that can benefit from pro-environmental change.

The barriers to environmental change are significant. Residents need to have a knowledge of the problem, knowledge of the action needed to prevent or rectify the problem, and the desire to do so. The desire can be intrinsic, but to create a real change in the presence of urban ecosystem services, the research suggests that the desire to change one's environment must come from an interaction with the environment in a way that reveals the benefits of ecosystem services. This change may come from

Significant correlations with demographics and canopy cover were only found between education level and income level.

Scales of environmental measurement do not promote choices and behaviors that create the scale of change needed to meet sustainability goals in most municipalities. When development is measured by the number of negative impacts on energy or water demands rather than on restorative properties, there is usually not a desire to create systems with site and natural systems in mind. Without a new term of measurement, degraded areas such as cities will be forced to seek the resources needed to support the city in areas well beyond its limits. Water is an example, where many large cities in the US do not have watersheds with the capacity to supply the region, not only because of high levels of population, but because universal landscape aesthetics where manicured lawns and luxurious golf courses create a demand on the systems that the region was never able to support. Installing water efficient fixtures in new residential homes is likely not going to fix the supply and demand issue alone. Switching from a low impact scale of how to be more efficient to a mind set of contribution, where residents are required to harvest, reclaim, and reuse water is one way to combat these problems on a greater scale needed to create sustainable regions.

There is a disconnect between many ecosystem services or ecological issues and daily life in urban areas. Waste is conveniently put out on the curb and taken away weekly, never to be seen again. Water, energy and light are conveniently delivered at the flip of a switch. Food is abundant and seasonality is no longer a problem. The public

relationship with vegetation is possibly the best ecosystem service that can be used to reconstruct issues of scale not only for the reasons previously mentioned throughout this report, but because it is probably one of the only services that the public interacts with in a way that is not abstracted as these other services has been. Home owners actively maintain their landscape and enjoy its benefits for a backyard get together. Drivers seek the shade to park their cars under on hot days and notice the absence when they have to get back in the car. Office dwellers can have a quick respite from the work day just by looking outside at the changing colors on the street trees. There are not just benefits, but locally there is also a seasonality that has the opportunity to create a connection with vegetation that may not be as concrete as other services.

The research shows that the only demographic groups to positively correlate with canopy cover was those with a high level of education and income. Even if findings did not prove to be as numerous as previously hoped, the high amount of positive correlations with questions relating to vegetation's relationship with other ecosystem services is promising. With 60% of residents also citing that they are making significant changes to the amount and variety of their landscape means that the public is taking advantage of the malleability of ecosystem services within their control. Even if the survey doesn't touch on how this may be altering the landscape of Portland and its neighborhoods, looking at the additional information provided by the GIS models shows that organizational involvement may have a big role in decision making and attitudes in

the public, and that these possibly small changes can produce a big change in the composition of a neighborhood in a resident's tenure.

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Appendix A:

Vegetation Survey

Urban Vegetation:
A Survey of Portland Area Residents

Please take this quick survey and return it in the enclosed envelope. If you have any questions about this survey, please contact Vivek Shandas at the email address or phone number provided below.

Thank you for your time and input!

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What is this survey?

The following survey is part of a study being conducted at Portland State University. We are hoping to learn more about how residents of our region feel about the environment and how they make decisions about yard care on their private property. Your input is *extremely valuable* and will give voice to the way the region accommodates future growth. We simply ask that you respond to each survey question honestly and to the best of your ability.

Your responses to all questions are *voluntary* and will remain *confidential* — attached is a consent form for you to keep for your records.

If we receive your response by **May 12, 2008** we will enter you in a drawing to win *one of four gift certificates of $100* for the Portland State University bookstore (we will need a phone number or email address).

What do we mean by Urban Vegetation?

Urban vegetation is grass, trees, shrubs, and other plants in the Portland metropolitan area.

In **public spaces** - this can be parks, forests, and street trees or other plants on public property (owned and maintained by local government).

On **private property** - this can be grass, trees, shrubs, or other plants on *your own* property.

Cover Photo Credit: Friends for Our Riverfront, http://www.friendsforourriverfront.org

1. In general, how much would you say each of the following activities *negatively affects* the environment? *(please circle only one item per statement)*

	Not at all (1) ---------- A lot (9)									*Don't Know (D.K.)*
a. Driving short distances	1	2	3	4	5	6	7	8	9	D.K.
b. Water flow from paved surfaces	1	2	3	4	5	6	7	8	9	D.K.
c. Emissions from public buses	1	2	3	4	5	6	7	8	9	D.K.
d. Bug killers on your lawn/garden	1	2	3	4	5	6	7	8	9	D.K.
e. Removal of streamside vegetation	1	2	3	4	5	6	7	8	9	D.K..
f. Pollution from manufacturing	1	2	3	4	5	6	7	8	9	D.K.
g. Building a new home	1	2	3	4	5	6	7	8	9	D.K.
h. Heating your home in winter	1	2	3	4	5	6	7	8	9	D.K.
i. Watering your lawn	1	2	3	4	5	6	7	8	9	D.K.

2. To what extent do you agree with each of the following statements? *(please circle only one item per statement)*

	Strongly Disagree (1) ------ Strongly Agree (9)									*Don't Know*
a. Neighborhood trees improve local air quality.	1	2	3	4	5	6	7	8	9	D.K.
b. Places with trees allow rain water to seep into the ground.	1	2	3	4	5	6	7	8	9	D.K
c. Lawns improve neighborhood air quality.	1	2	3	4	5	6	7	8	9	D.K
d. Streamside vegetation improves water quality.	1	2	3	4	5	6	7	8	9	D.K
e. Salmon require warm water to survive.	1	2	3	4	5	6	7	8	9	D.K
f. The planning department coordinates water supply.	1	2	3	4	5	6	7	8	9	D.K.
g. Public input is required when planning for the city.	1	2	3	4	5	6	7	8	9	D.K
h. The Willamette River is clean enough for swimming.	1	2	3	4	5	6	7	8	9	D.K.
i. Drinking water for our region comes from underground.	1	2	3	4	5	6	7	8	9	D.K

3. How much do you know about each of the following topics? *(please circle only one item per statement)*

	Not at all (1) ---------- A lot (9)									*Don't Know*
a. Different types of trees	1	2	3	4	5	6	7	8	9	D.K.
b. Different types of birds	1	2	3	4	5	6	7	8	9	D.K.
c. Lawn care practices	1	2	3	4	5	6	7	8	9	D.K.
d. Nature in neighborhoods	1	2	3	4	5	6	7	8	9	D.K.
e. Hydrological cycle	1	2	3	4	5	6	7	8	9	D.K.
f. Ecosystem services	1	2	3	4	5	6	7	8	9	D.K
g. Climate change science	1	2	3	4	5	6	7	8	9	D.K.
h. Environmental policies	1	2	3	4	5	6	7	8	9	D.K.

For Q4 – Q8, rate each item on a scale of 1 – 6, where *1 = Not at All Important* and *6 = Extremely Important*. You can also choose *No Opinion* (N.O.) or *Don't Know* (D.K.).

4. How would you rate the overall importance of having vegetation in our region?

Not at All Important (1) ----------Extremely Important (6)							*No Opinion*	*Don't Know*
1	2	3	4	5	6		N.O.	D.K.

5. How would you rate the overall importance of having vegetation on <u>your own property</u>?

Not at All Important (1) ----------Extremely Important (6)							*No Opinion*	*Don't Know*
1	2	3	4	5	6		N.O.	D.K.

6. How important, would you say, are the following reasons for having vegetation <u>in public spaces</u> (such as parks or streets) of our region?

	Not at All (1) ------ Extremely (6)						*No Opinion*	*Don't Know*
a. Physical beauty	1	2	3	4	5	6	N.O.	D.K.
b. Having a place for recreation or relaxation	1	2	3	4	5	6	N.O.	D.K.
c. Improved air quality	1	2	3	4	5	6	N.O.	D.K.
d. Reduced potential for floods or erosion	1	2	3	4	5	6	N.O.	D.K.
e. Cooling and/or shading in hot/sunny weather	1	2	3	4	5	6	N.O.	D.K.
f. Improved social quality of the community	1	2	3	4	5	6	N.O.	D.K.
g. Increased property value	1	2	3	4	5	6	N.O.	D.K.
h. Habitat for wildlife (such as birds or squirrels)	1	2	3	4	5	6	N.O.	D.K.
i. Reducing crime	1	2	3	4	5	6	N.O.	D.K.
j. Helping with medical healing	1	2	3	4	5	6	N.O.	D.K.

7. How important, would you say, are the following reasons for having vegetation on <u>your own property</u>?

	Not at All (1) ------Extremely (6)						*No Opinion*	*Don't Know*
a. Physical beauty	1	2	3	4	5	6	N.O.	D.K.
b. Having a place for recreation or relaxation	1	2	3	4	5	6	N.O.	D.K.
c. Improved air quality	1	2	3	4	5	6	N.O.	D.K.
d. Reduced potential for floods	1	2	3	4	5	6	N.O.	D.K.
e. Cooling and/or shading in hot/sunny weather	1	2	3	4	5	6	N.O.	D.K.
f. Improved social quality of your community	1	2	3	4	5	6	N.O.	D.K.
g. Increased property value	1	2	3	4	5	6	N.O.	D.K.
h. Habitat for wildlife (such as birds or squirrels)	1	2	3	4	5	6	N.O.	D.K.
i. Reducing crime	1	2	3	4	5	6	N.O.	D.K.
j. Helping with medical healing	1	2	3	4	5	6	N.O.	D.K.

8. How important are the following reasons for *NOT* having vegetation on your property?

	Not at all (1) --------- Extremely (6)						*No Opinion*	*Don't Know*
a. Costly	1	2	3	4	5	6	N.O.	D.K.
b. Hazardous	1	2	3	4	5	6	N.O.	D.K.
c. Blocks views	1	2	3	4	5	6	N.O.	D.K.
d. Time required	1	2	3	4	5	6	N.O.	D.K.
e. Difficult to maintain	1	2	3	4	5	6	N.O.	D.K.
f. Doesn't fit with the neighborhood	1	2	3	4	5	6	N.O.	D.K.
g. Other _____	1	2	3	4	5	6	N.O.	D.K.

9. To what extent do you agree with each statement?

	Strongly Disagree (1) ----- Strongly Agree (6)							
a. I would like to have more large trees on my property.	1	2	3	4	5	6	N.O.	D.K.
b. Amount of yard maintenance matters in my decisions.	1	2	3	4	5	6	N.O.	D.K.
c. Having a garden is important to me.	1	2	3	4	5	6	N.O.	D.K.
d. I enjoy yard work.	1	2	3	4	5	6	N.O.	D.K.
e. My neighborhood is full of large trees.	1	2	3	4	5	6	N.O.	D.K.
f. Large trees have damaged my home.	1	2	3	4	5	6	N.O.	D.K.
g. The Portland region should have more trees.	1	2	3	4	5	6	N.O.	D.K.
h. I have done everything I can to improve my yard.	1	2	3	4	5	6	N.O.	D.K.
i. My neighbors work on their yard more than I do.	1	2	3	4	5	6	N.O.	D.K.

10. Of the existing vegetation on your property, how much would you say is made up of each of the following?

a. Trees	□ Minimal (0-25%)	□ Moderate (26-75%)	□ Most (76-100%)
b. Shrubs	□ Minimal (0-25%)	□ Moderate (26-75%)	□ Most (76-100%)
c. Grass	□ Minimal (0-25%)	□ Moderate (26-75%)	□ Most (76-100%)
d. Other plants	□ Minimal (0-25%)	□ Moderate (26-75%)	□ Most (76-100%)

11. Who takes care of the vegetation in your yard?
(If more than one option is correct, choose the one that is most often correct.)

□ You, your spouse, or another house-mate (Go to Q12)
□ A landscaping service or company (Skip to Q16)
□ Other: _____ (Skip to Q16)

12. How important are the following things when caring for your yard?

	Not at all (1) --------- *Extremely (6)*						*No Opinion*	*Don't Know*
a. Technical expertise	1	2	3	4	5	6	N.O.	D.K.
b. Cost	1	2	3	4	5	6	N.O.	D.K.
c. How it looks	1	2	3	4	5	6	N.O.	D.K.
d. Benefits from vegetation (such as shade)	1	2	3	4	5	6	N.O.	D.K.
e. Environmental concerns	1	2	3	4	5	6	N.O.	D.K.
f. What neighbors are doing	1	2	3	4	5	6	N.O.	D.K.
g. Other _____	1	2	3	4	5	6	N.O.	D.K.

13. How much have you changed the amount or types of vegetation on your property in the time you have lived in your current home? *(Choose only one)*

□ Not at all □ Only slightly □ Somewhat □ Significantly □ Don't know

14. In the summer, how many hours per week do you generally spend on yard care? *(Choose only one)* □ 0-2 hours □ 3-5 hours □ 6-10 hours □ More than 10 hours

15. In the summer, how often do you apply the following to any part of your yard?

	Never	Rarely	Yearly	Few times per year	Monthly	Weekly
a. Chemical Fertilizer	□	□	□	□	□	□
b. Organic or Natural Fertilizer	□	□	□	□	□	□
c. Herbicide/Weed Killer	□	□	□	□	□	□
d. Pesticides/Bug Killer	□	□	□	□	□	□

16. On average during <u>the summer</u> how often do you use water outdoors? *(Choose one)*

□ Never/Rarely
□ Monthly
□ A few times per month
□ Weekly
□ A few times per week
□ Daily

17. On average, what percentage of your total household water use <u>during summer</u> is for outdoors purposes (e.g. watering lawns/plants, washing car, etc)?

□ 0-25% □ 26-50% □ 51-75% □ 76-100% □ Don't Know

18. In <u>the summer</u>, what time of day do you use water outdoors most often? *(Choose one)*

□ Early morning
□ Late morning to afternoon
□ Evening
□ Overnight
□ Varies day to day
□ Never

19. In what ways do you use water for your outdoor vegetation? *(Choose all that apply)*

□ Hose
□ Sprinklers on a hose
□ Sprinklers in the ground
□ Watering can or other container
□ Drip irrigation
□ Other: _____

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20. What is your age? _____

21. What race and/or ethnicity do you consider yourself?

□ White
□ Hispanic/Latino
□ Black/African American
□ Asian/Asian American
□ Native American/American Indian
□ Other: _____

22. What is your highest level of education? *(Choose only one)*

□ Less than High School
□ High School Degree
□ Some College
□ Associate's Degree
□ Bachelor's Degree
□ Post-Graduate Degree

23. What was your approximate household income in 2007 before taxes?
(Choose only one)

□ Less than $15,000
□ $15,000 -24,999
□ $25,000-34,999
□ $35,000-49,999
□ $50,000-74,999
□ $75,000-99,999
□ $100,000+

24. How many people live in your household (including you)? _____

25. How long have you lived in your current home? ____ Years ___ Months

26. Do you own or rent your home? □ Own □ Rent

27. In what kind of home do you live?

□ Single-family detached house
□ Single-family attached house or townhouse
□ Condominium or apartment building
□ Other: _____

Can we contact you if we have additional questions regarding your property management? If yes, please provide your phone number and/or email address:_____.

THANK YOU!!

Please return your completed survey in the envelope provided — no stamp necessary.

Please use this space for any additional comments you may have about the issues raised in this survey.

Thank you for your time and input!

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Appendix B:

All Significant correlations calculated using the Pearson Correlation Coefficient Calculated using IBM SPSS Statistics

Demographic Correlations			
Survey Question		Demographic	Correlation
Basic knowledge of environmental issues and benefits of vegetation			
Q1A	Driving short distances negatively affects the environment	Education	.094*
Q1B	Water flow from paved surfaces negatively affects the environment	HH Income	-.086*
Q1C	Emissions from public buses are negative	Age Education HH Income Tenure	.224** -.146** -.167** .083*
Q1D	Bug killers on your lawn/garden negatively affects the environment	Education	.086*
Q1F	Pollution from manufacturing negatively affects the environment	Age HH Income	-.085* -.080*
Q1G	Building a new home negatively affects the environment	Age Education	-.162** .185**
Q1H	Heating your home in the winter negatively affects the environment	Education	.126**
Q1I	Watering your lawn negatively affects the environment	Age Education	-.149** .164**
Q2A	Neighborhood trees improve local air quality	Age HH Income	.091* -.111**
Q2C	Lawns improve neighborhood air quality	Age Education HH Income	.233** -.216** -.085*
Q2D	Streamside vegetation improves water quality	Race Education	-.081* .081*
Q2E	Salmon require warm water to survive	Race	.102*
Q2F	The planning department coordinates water supply	Education HH Income	-.153* -.283**
Q2G	Public input is required when planning for the city	Age	-.120**
Q2H	The Willamette River is clean enough for swimming	Age	.106**
Q2I	Drinking water for our region comes from underground	Race	.121**
Q3A	Respondent has a high self reported knowledge of different types of trees	Education	.091*

Q3B	Respondent has a high self reported knowledge of different types of birds	Age	.080*
Q3C	Respondent has a high self reported knowledge of lawn care practices	Age Education	.102** -.084*
Q3D	Respondent has a high self reported knowledge of nature in neighborhoods	Race	-.112**
Q3E	Respondent has a high self reported knowledge of the hydrological cycle	Age Education HH Income	-.115** .265** .169**
Q3F	Respondent has a high self reported knowledge of ecosystem services	Education HH Income	.201** .145**
Q3G	Respondent has a high self reported knowledge of climate change science	Age Education HH Income	-.095* .211** .156**
Q3H	Respondent has a high self reported knowledge of environmental policies	Education HH Income	.237** .181**

Attitudes and perceptions of the value of urban vegetation			
Q4	The overall importance of having vegetation in our region is extremely important	Education	.110**
Q5	The overall importance of having vegetation on your own property is extremely important	Education	.106**
Q6A	Vegetation in public spaces is extremely important for physical beauty	Age Education HH Income	-.205** .254** .232**
Q6C	Vegetation in public spaces is extremely important for improved air quality	Age HH Income	.102** -.172**
Q6D	Vegetation in public spaces is extremely important for reduced potential for floods or erosion	HH Income	-.145**
Q6E	Vegetation in public spaces is extremely important for cooling and/or shading in hot/sunny weather	Age HH Income	.088* -.093*
Q6F	Vegetation in public spaces is extremely important for improved social quality of the community	Age Education	-.136** .167**
Q6H	Vegetation in public spaces is extremely important for habitat for wildlife (such as birds and squirrels)	HH Income	-.136**
Q6I	Vegetation in public spaces is extremely important for reducing crime	Race	.088*
Q6J	Vegetation in public spaces is extremely important for helping with medical healing	HH Income	-.180**

Q7A	Vegetation on your own property is extremely important for physical beauty	Education	.127**
Q7B	Vegetation on your own property is extremely important for having a place for recreation or relaxation	Age Education	-.108** .078*
Q7C	Vegetation on your own property is extremely important for improved air quality	Age HH Income	.119** -.207**
Q7D	Vegetation on your own property is extremely important for reduced potential for floods or erosion	HH Income	-.191**
Q7F	Vegetation on your own property is extremely important for improved social quality of the community	Age Education	-.102** .083*
Q7H	Vegetation on your own property is extremely important for habitat for wildlife (such as birds and squirrels)	HH Income	-.148**
Q7I	Vegetation on your own property is extremely important for reducing crime	Race	.106*
Q7J	Vegetation on your own property is extremely important for helping with medical healing	HH Income	-.172**
Q8A	An important reason for not having vegetation on your own property is because it is costly	Education HH Income	-.091* -.080*
Q8B	An important reason for not having vegetation on your own property is because it is hazardous	Education	-.102*
Q8C	An important reason for not having vegetation on your own property is because it blocks views	Age	.080*
Q8F	An important reason for not having vegetation on your own property is because it doesn't fit with the neighborhood	Race	.084*
Q9A	I would like to have more large trees on my property	Age Education	-.246** .083*
Q9C	Having a garden is important to me	Age Education	-.089* .107**
Q9E	My neighborhood is full of large trees	Age HH Income	.083* .091*
Q9F	Large trees have damaged my home	Age	.115**
Q9G	The Portland region should have more trees	Age Education	-.077* .087*
Q9H	I have done everything I can to improve my yard	Age	.213**
Q9I	My neighbors work on their yard more than I do	Age	-.080*

Individual behavior on private property			
Q10A	Of the existing vegetation on your own property, how much would you say is made up of trees	Education HH Income	.093* .118**

Q10B	Of the existing vegetation on your own property, how much would you say is made up of shrubs	Age	.193**
Q10C	Of the existing vegetation on your own property, how much would you say is made up of grass	Education HH Income	-.128** -.104**
Q11	Who takes care of the vegetation in your yard	Age HH Income	.150** .091*
Q12A	Technical expertise is important when caring for your yard	Age Education	.142** .092*
Q12B	Cost is important when caring for your yard	HH Income	-.138**
Q12C	How it looks is important when caring for your yard	HH Income	.086*
Q12D	Benefits from vegetation (such as shade) is important when caring for your yard	Age	.092*
Q12E	Environmental concerns are important when caring for your yard	HH Income	-.117**
Q15A	Chemical fertilizer is never (1)/weekly (6) applied during the summer	Age Education	.230** -.170**
Q15B	Organic or natural fertilizer is never (1)/weekly (6) applied during the summer	Age	.095*
Q15C	Herbicide/weed killer is never (1)/weekly (6) applied during the summer	Age Education	.184** -.169**
Q15D	Pesticides/bug killer is never (1)/weekly (6) applied during the summer	Age Education	.199** -.157**
Q17	The percentage of your total household water use during the summer for outdoor purposes is 0-25% (1)/76-100% (6)	Age Race	.120** -.099*
Q18	I water in the early morning (1)/never (6) during the summer	Age	-.097*

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).